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THE NOVEMBER SCIENTIFIC MONTHLY

Edited by

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THE SCIENTIFIC MONTHLY

NOVEMBER, 1939

RECENT PROGRESS IN PLANT BREEDING

By E. B. BABCOCK

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THE utter futility of attempting to present the accomplishments of breeders of the various agricultural and horticultural crop plants in one short paper must be obvious, at least to those who are familiar with the wide scope of plant breeding activity in nearly all countries. For this reason an attempt will be made to review some aspects of recent progress in plant breeding in such a way as to indicate promising lines of future progress. If, in so doing, the layman is disappointed by the paucity of startling achievements, it is hoped that the plant breeder will be encouraged and stimulated by the interesting possibilities which are being opened up by recent research in genetics, cytogenetics and plant physiology.

In 1922 Edward M. East[1] published a brief but penetrating review of the progress in genetics since 1900. He did not touch on applied genetics, but gave an excellent summary in terms of general conclusions regarding the laws of heredity, the mechanism of heredity and the bearing of genetics on evolution. Let us now consider the status of plant breeding at about the same time by briefly mentioning a few events and publications which may serve as guides in our effort to evaluate the progress that has been made during the past decade or two. To save time, I shall look backward at only three phases of plant breeding; but, as a matter of fact, the recent progress in these fields involves the application of the most advanced theoretical genetics and cytogenetics. These three phases may be designated as breeding plants to order, utilizing hybrid vigor and breeding for disease resistance.

In 1921 East and Jones[2] published a paper on round tip tobacco—a plant "made to order," illustrating the application of genetic principles to produce a new type of crop plant to meet the grower's demand by the crossing of existing varieties of a single species. This of course was not the first achievement of this sort. The creation of new varieties by combining in hybrids the desirable characteristics from two different parents had been accomplished even before the rediscovery of Mendel's laws in 1900. But those earlier plant breeders, including some who were prominent in the early years of the present century, and even some who are engaged in empirical plant breeding at present, were working more or less blindly and often without any appreciation of the importance of carrying on to the second generation after crossing two varieties. By the

[1] E. M. East, *Jour. Heredity*, 13: 207–214, 1922.

[2] E. M. East and D. F. Jones, *Jour. Heredity*, 12: 51–56, 1921.

end of the second decade of the present century most scientifically trained plant breeders were well aware of the practical value of applying the Mendelian principles in the work of plant improvement by means of hybridization. And now, as we near the end of the fourth decade, one can hardly find a single important crop plant or ornamental flower that has not been improved in productivity or quality, at least in some country or countries, by systems of breeding based on the Mendelian principles. The breeding of plants to order will be further illustrated in connection with the breeding of disease-resistant plants.

In 1919 East and Jones[3] published their monograph on "Inbreeding and Outbreeding," in which they called attention to the probable future importance of heterosis or hybrid vigor in crop production. They emphasized the great potential value of the so-called double-crossed corn in increasing the yield and uniformity of maize, the most important field crop in this country. As early as 1910 G. H. Shull and East had independently applied Johannsen's pure line concept to maize, which is naturally cross-fertilized, and after demonstrating the extremely deleterious effects of inbreeding on self-fertilized lines of maize, they had discovered that crossing certain of these inbred lines would produce first generation hybrids with high yield and a much more uniform crop than the original unselected variety. Soon it was discovered that some of these first generation hybrids are more resistant to diseases and pests than the original varieties. Then Jones began to experiment with secondary crosses between various first generation hybrids, with the idea that in some such crosses there should be still further increase in vigor and yield. The result was his recommendation that double-crossed corn, produced by crossing carefully selected first generation hybrids between inbred lines, should be used in producing the future supply of seed corn.

It required another decade or so of experimentation and demonstration to convince some of the leading corn breeders and corn seed growers that properly produced double-crossed seed is the best from most points of view. The testing of many different inbred strains as parents of first generation hybrids and the testing of these single-cross hybrids in various combinations to produce the best double-cross hybrids is still going on and no doubt will continue indefinitely at least in certain experiment stations. But it is now fairly safe to predict that double-crossed hybrid seed will soon be used for the bulk of the nation's corn crop. According to Jungenheimer,[4]

> comparisons in many states indicate that *certain* corn hybrids are more able to withstand drouth, wind, diseases, insects and other unfavorable conditions than the best standard varieties. These qualities reduce the hazards of corn production, with resultant benefits to the grower and consumer. . . . The first commercial hybrid seed corn was produced in Connecticut about 17 years ago. Corn belt hybrids adapted to the corn belt have been available for only about 10 years, but during that time their use has shown a phenomenal increase. In fact the acreage of hybrid corn has doubled and trebled every year during the past three or four years. Almost unknown to the average corn grower four years ago, about 17,000,000 acres were planted with hybrid seed corn in 1938. This is over one seventh of the nation's total corn acreage.

It is safe to say that the growers who plant properly certified hybrid corn seed are not only increasing their yield per acre but are also insuring their crop to some extent against possible damage. Under our present system of crop control, this insurance of crop yield and increased yield per acre is of even greater importance to the producer than in the past.

[3] E. M. East and D. F. Jones, "Inbreeding and Outbreeding," 285 pp. Philadelphia and London, 1919.

[4] R. W. Jungenheimer, *Kansas Agr. Exp. Sta. Circular* No. 196, 1939.

The possibility of utilizing heterosis in the improvement of other crops depends largely upon the practicability of producing the hybrid seed at a cost that will not be prohibitive to the grower. An illustration of its use in an important vegetable crop is the recent report of two Russians, Selivanov and Alpat'ev[5] on "Heterosis in Tomatoes in the Canning Industry." Thirty-five varietal hybrids were tested. All were earlier in maturity than either parent; eleven exceeded the better parent in yield by 20 to 51 per cent., ten by 10 to 20 per cent. and the rest were slightly superior or equal to the better parent. The hybrids were better developed and more disease-resistant than their parents and in fruit quality they were equal to the standard varieties. The use of hybrid seed on the collective farms is recommended and the most favorable parental combinations are indicated. Another possible use for heterosis is found in the production of faster-growing forest trees. Experiments in this direction are being conducted by the Institute of Forest Genetics of the U. S. Forest Experiment Station. Still another use for it may be found in the production of rapidly growing hard-wood trees like the black walnut.

Turning now to the third phase, breeding for disease resistance, the pioneer work of W. A. Orton[6] extended from 1900 to 1911, and that decade of work by one man pointed the way to a more permanent agriculture. In the following decade progress was slow, but by 1921 the work of Norton[7] on breeding asparagus resistant to rust, of L. R. Jones[8] on breeding cabbage resistant to fusarium and of G. M. Reed[9] on resistance and susceptibility of oats to various fungi had stimulated wide-spread interest in the combatting of plant diseases by the breeding of resistant commercial varieties. As a result, during the last twenty years new varieties which are resistant to fungus diseases or to insects or nematodes have been produced in such important field crops as barley, beans, cowpeas, cabbage, canteloupe, corn, cotton, lettuce, oats, peas, potatoes, sorghum, spinach, sugar beets, tobacco, tomatoes, watermelons and wheat.

Much of the earlier work on disease-resistant varieties consisted merely of the selection of resistant strains out of old varieties. But the classical work of Orton on breeding wilt-resistant watermelons began with hybridization of the watermelon and the field melon or citron because the latter was resistant to the disease, although of no value as a table fruit. By raising successive generations from this cross and repeatedly selecting seed from the most promising plants, wilt-resistant watermelons of commercial value were finally obtained. Many of the problems involved in the breeding of disease-resistant varieties by hybridization are no more difficult than that of breeding wilt-resistant watermelons. But in some cases the problems are complicated by the necessity of using distinct species having different chromosome numbers.

As an illustration of this more complex type of problem, let us consider as briefly as possible some of the progress that has been made in breeding for resistance to the black stem rust in wheat. This one phase of wheat breeding has a long history, including many interesting angles and details; it will be possible here merely to bring out some of the highlights in a varied panorama of agricultural activity.

[5] M. W. Selivanov and A. V. Alpat'ev, *Plodoovoscnoe Khozjaistvo* (Fruit and Vegetable Growing), 1: 21–24, 1938 (abstract in *Plant Breeding Abstracts*, 8: 497, 1938).

[6] W. A. Orton, U. S. Dept. Agr. Yearbook 1908: 453–464.

[7] J. B. Norton, U. S. Dept. Agr. *B. P. I. Bull.*, 263, 1913.

[8] L. R. Jones, *Wis. Agr. Exp. Sta. Res. Bull.*, 48, 1920.

[9] G. M. Reed, *Mo. Agr. Exp. Sta. Res. Bull.*, 37, 1920.

The black stem rust has long been known as a serious menace to wheat production in all the important wheat-growing countries, and a great many efforts were made to produce varieties resistant to the fungus by the older and simpler methods of plant breeding. In this earlier work only common varieties of wheat were used either as sources of new selected strains or as parents of hybrids. The common wheats are varieties of *Triticum vulgare;* they all have 21 pairs of chromosomes; and none are known to be fully resistant to black stem rust. The chief difficulties in breeding for resistance among the common wheats alone are (a) the natural variability (occurrence of physiologic races) in the parasitic fungus itself and (b) the fact that none of the many otherwise excellent *vulgare* varieties carry genetic factors for immunity to stem rust. In spite of these difficulties a number of excellent new varieties that were partially resistant to the disease were produced by crossing common wheats and selecting in later generations. But this was not enough to insure the wheat crop against possible loss from stem rust. As recently as 1935 an epidemic of black stem rust in North Dakota resulted in losses estimated at $100,000,000. Now it had been known for many years that some of the *Triticum* species having only 14 pairs of chromosomes were immune to this disease. A variety of *T. dicoccum,* known as white spring emmer, has been grown in this country for at least 50 years and is known to be nearly immune to stem rust. In 1920 Hayes, Parker and Kurtzweil[10] from the results of crossing this emmer with common wheat, predicted that the transfer of this near immunity from emmer to common wheat was possible. This job, however, proved to be very difficult due to the high degree of sterility of the first generation hybrids and the linkage of resistance with undesirable emmer characters. It was not until 1930 that McFadden[11] of South Dakota succeeded in combining the rust resistance of Yaroslav emmer with the commercial qualities of Marquis, a valuable common wheat, through hybridization and selection. As a result he introduced two new varieties, H-44 and Hope; and in the all-important mature plant stage these two varieties have been found nearly immune from all the physiologic forms of stem rust. This important step made possible the production of many other nearly rust-free varieties by hybridization either of H-44 or Hope with other common wheats.

As one illustration of this last phase of the progress in wheat breeding, let me mention the work of our own experiment station in breeding a rust-resistant wheat for California. Realizing that many California wheat-growers prefer the variety called White Federation, which is very susceptible to rust, Briggs[12] has developed a rust-resistant White Federation wheat by first crossing White Federation with Hope and then by repeatedly backcrossing the resistant hybrids to White Federation. By a similar system of hybridization, followed by backcrossing selected hybrids to the variety into which resistance is being introduced, Briggs is working toward the combination of rust resistance with resistance to bunt or stinking smut and resistance to the Hessian fly, all in the same commercial variety.

Meanwhile, the physiological nature of disease resistance is becoming better understood, not only in wheat but in many other crop plants. At the same time the genetics of susceptibility, resistance and immunity, like the genetics of other important qualities, is being worked out for many different crop plants. As this knowledge becomes avail-

[10] H. K. Hayes, J. H. Parker and C. Kurtzweil, *Jour. Agr. Research,* 19: 523–542, 1920.

[11] E. S. McFadden, *Jour. Amer. Soc. Agron.,* 22: 1020–1034, 1930.

[12] F. N. Briggs, *Am. Nat.,* 72: 285–292, 1938.

able to scientific plant breeders, the progress in plant improvement will become more certain, if not more rapid. Concerning wheat, for example, Clark[13] states: "While much work has been accomplished with wheat, the peak of research surely has not yet been reached. Many problems remain to be solved, and even greater results than those obtained in the past may be expected in the future." In general, it is worthy of emphasis that future progress in plant breeding is to some extent dependent on more complete genetic analysis of all important crop plants. First the tagging of the chromosomes, then the mapping of the chromosomes, as has been done in Drosophila, will give the only sure foundation for the breeding of new varieties "to order." Such genetic analysis is well advanced in maize, and some progress has been made with barley, garden peas, common beans, rice, oats, wheat, soy beans, cotton, flax, tomatoes and tobacco, as well as the garden snapdragon, Japanese morning glory, sweet pea and other ornamental flowers.

As an illustration of a still more advanced type of plant breeding, let us consider the use of an amphidiploid hybrid in bridging two species which produce completely sterile hybrids. Fortunately we have an interesting illustration of this from a recent achievement in breeding disease-resistant tobacco. Commercial tobacco, *Nicotiana Tabacum*, is seriously affected by a virus disease called tobacco mosaic. Now it happens that another species of *Nicotiana, N. glutinosa,* is hypersensitive to this same mosaic virus, but because of this hypersensitivity each infected area is self-limiting and therefore *Nicotiana glutinosa* is, practically speaking, immune to the disease. Dr. F. O. Holmes, of the Rockefeller Institute for Medical Research, was interested in breeding mosaic immune commercial tobacco. In the hope of introducing immunity from *N. glutinosa* into *N. Tabacum*, he hybridized the two species, but all his first generation hybrids were completely sterile. Now it happens that two of my colleagues, R. E. Clausen and T. H. Goodspeed,[14] had been interested in the cytogenetics of *Nicotiana* for many years and, among the various experimental hybrids that they studied, were some between *N. glutinosa* and *N. Tabacum*. These two species differ in many morphological characters and, as would be expected, the F_1 hybrids exhibit a combination of various characters from the two species. Now *N. glutinosa* has 12 pairs of chromosomes, whereas *N. Tabacum* has 24 pairs; so the F_1 hybrids should have 36 chromosomes, 12 *glutinosa* + 24 *Tabacum*, and because of this unbalanced relation between the chromosomes these hybrids would be expected to be highly or completely sterile. Such indeed proved to be true except for one of the F_1 hybrids, which proved to be fertile and which a year later produced a family of 65 plants which were uniformly fertile and were found to have 72 instead of 36 chromosomes. Evidently the original fertile hybrid plant arose from a doubling of the chromosome number immediately or soon after fertilization by which a tetraploid hybrid with 36 *pairs* of chromosomes was produced; and these 36 pairs consisted of the normal diploid complement of *glutinosa* + the normal diploid complement of *Tabacum*. In other words, the fertile F_1 hybrid was an amphidiploid and, since each parental set of chromosomes behaved normally in gamete formation, the hybrid was fertile and when selfed produced a uniform family of amphidiploids. This new type, combining characteristics from two very distinct species, was named *Nicotiana digluta*. Since *digluta* has a complete complement of *glutinosa* chromosomes as

[13] J. A. Clark, U. S. Dept. Agr. Yearbook, 1936: 207–302.

[14] R. E. Clausen and T. H. Goodspeed, *Genetics*, 10: 278–284, 1925.

part of its hereditary mechanism, it of course carries the factor or factors for hypersensitivity to the mosaic virus. So when Holmes appealed to Clausen for suggestions as to how he might introduce this practical immunity into commercial tobacco, Clausen sent him seed of *N. digluta* and suggested a plan of procedure. By crossing *digluta* with several varieties of commercial tobacco and backcrossing mosaic-free hybrids to the *Tabacum* parent repeatedly for several generations, Holmes has established several new lines that have the characteristics of commercial tobacco and are as immune to mosaic as *glutinosa*. A cytogenetic analysis of just what took place among the chromosomes in achieving this result has not been made. One possible explanation is that a translocation occurred between the *glutinosa* chromosome carrying the hypersensitivity gene, the N factor of Holmes[15] and one of the *Tabacum* chromosomes. The true explanation must await further cytogenetic research. Meanwhile, this experience in tobacco breeding illustrates how practical results are sometimes obtained without our knowing the exact scientific explanation of how they happened. It also provides a fine illustration of an important practical application following upon a purely theoretical achievement, namely, the discovery of the amphidiploid hybrid, *Nicotiana digluta*, which was a gift of nature.

It should be noted that the same objective could have been reached if Holmes had had a tetraploid form of *Tabacum* with which to work instead of *N. digluta*. By crossing such a tetraploid with *N. glutinosa* his first hybrid would have had 12 *glutinosa* + 48 *Tabacum* chromosomes just as before, and the same program of backcrossing to commercial tobacco would have been in order.

This brings up the subject of the artificial production of tetraploids from diploids and of amphidiploids from normal first-generation hybrids between species. And this is only one phase of very important recent developments in cytogenetics. It will serve to introduce the concluding portion of this paper in which a brief review will be attempted of recent progress in plant breeding technique.

Several different methods are known by which the chromosome complement of a plant may be doubled. In briefest summary these are as follows. First, the the decapitation method of Winkler[16] has been used recently by Greenleaf[17] with certain modifications in the production of amphidiploids from F_1 hybrids between species of *Nicotiana*. Second, subjection of the plant to abnormal temperatures for the purpose of accelerating or retarding the process of cell division has been used by Randolph[18] and others with success. Third, the use of x-rays and other types of radiant energy on seeds, pollen and other parts of the plant, as discovered by Goodspeed[19] is a possible method of producing tetraploids. Fourth, the application of various poisons will retard cell division, as was first demonstrated by Němec[20] in 1904, and will sometimes result in tetraploid offspring, as has recently been proved by Nebel,[21] Blakeslee and co-workers[22] and many others.

Following the artificial induction of tetraploids of a given species or variety, it is a simple matter to obtain triploids by crossing tetraploids with diploids.

[15] F. O. Holmes, *Phytopathology*, 28: 553–561, 1938.

[16] H. Winkler, *Zeitschr. Bot.*, 2: 1–38, 1910.

[17] W. H. Greenleaf, *Jour. Heredity*, 29: 451–464, 1938.

[18] L. F. Randolph, *Jour. Agr. Research*, 50: 591–605, 1935.

[19] T. H. Goodspeed and A. R. Olson, *Proc. Nat. Acad. Sci.*, 14: 66–69, 1928.

[20] B. Němec, *Pringsh. Jahrb. Wiss. Bot.*, 39: 645–730, 1904.

[21] B. R. Nebel, *Biol. Bull.*, 73: 351–352 (Oct.), 1937; *Nature*, 140: 1101 (Dec.), 1937.

[22] A. F. Blakeslee, *et al.*, Carnegie Inst. Wash. Year Book No. 36: 38–44 (Dec.), 1937.

Since triploids are generally highly or completely sterile, it is sometimes possible to produce vegetatively propagated seedless fruits of great horticultural value by this method. Whether in the production of seedless fruits or in the creation of amphidiploids which may be directly useful or used indirectly in further breeding operations, the saving of time in obtaining the desired result stands out as an important consideration.

Other valuable time-saving techniques have been devised in recent years, of which the following will serve as examples. By artificially controlling the length of daylight, two varieties or species which normally flower at different times may be brought into bloom simultaneously, thus facilitating hybridization between forms with short-lived pollen. Vernalization, or advancement of the rate of development of plants by means of pretreatment of the seed, provides another way of synchronizing the flowering periods of unlike species and varieties. Whole plants or flowering branches of one variety or species may be kept in nutrient solutions of chemicals or in cold storage, thus insuring available pollen for crosses on another variety or species. In the work of purification of material by repeated inbreeding or in repeated selection in successive hybrid generations, time can sometimes be saved by growing successive generations alternately in two different localities without waiting for recurrence of a favorable season in a single location. In this connection artificial methods of breaking the normal rest period of the seeds are sometimes utilized.

One of the most interesting and valuable time-saving techniques is the culture of embryos in nutrient media. The use of nutrient media in the culture of orchid seedlings has been a standard procedure for years. The possibility of using this method to insure germination and hasten development in other genera which are normally slow and irregular in germination does not seem to have been appreciated until recently. Dr. W. E. Lammerts, of the Armstrong Nursery Company, is engaged in the breeding of roses and peaches and some other fruits. In order to hasten germination and subsequent development, he removes the coverings from the embryos and places each embryo in a small vial of nutrient agar. The majority of the embryos germinate promptly and can soon be transferred to tiny pots of sand in the greenhouse, after which they are carried along by transplanting as rapidly as possible. Dr. Lammerts writes (unpublished data) that he has obtained a flower on a hybrid rose seedling within six months after culturing the embryo. He also states that vitamin B_1 has been very effective in giving higher percentages of germination in certain cultures where the embryo failed in many cases to form roots. Also the number of roots is much greater in the vitamin treated cultures than in the controls, so that transplanting to the little sand pots is easier. Furthermore, in hybrid peaches the embryo cultured trees develop more rapidly. For example, from peach crosses made in the spring of 1936, 123 trees were grown from cultured embryos and 117 from seeds germinated by the usual method of stratification. Of the 123 embryo cultured trees, 113 flowered and 71 fruited in 1938; whereas, of the 117 grown from stratified seeds, only 65 flowered and 36 fruited in 1938. Also there was a greater number of flowers per tree in the embryo cultured group. Dr. Lammerts is cooperating with Dr. Bonner of the California Institute of Technology in testing nicotinic acid, theelin and ascorbic acid as aids in the embryo culture work. Regarding roses there seems to be no doubt that embryo culture is worth while; and as for peaches Lammerts is convinced that embryo culture pays for the following reasons: (1) the higher percentage of

germination obtained; (2) the securing of a more representative random sample as a result of the higher percentage of germination; (3) the speeding up of the life cycle so that a two-year breeding program can be followed. Perhaps the most outstanding results are those obtained with apricots, which are well adapted to embryo culture technique, both as regards high percentage of germination and rapid, vigorous growth of seedlings.

Even in so brief a discussion of technique as this, one must not fail to mention the importance of cytology in plant breeding and to acknowledge the debt we owe to such pioneers as Belling, who devised the iron-aceto-carmine smear method as an aid in the rapid determination of chromosome numbers. This method with its many later modifications has perhaps done more for the advancement of plant breeding than any other single technique. Many of the demands made of the plant breeder can be met only by the use of two or more distinct species. The well-informed breeder, about to start a new project, will insist on knowing the chromosome numbers of the species and forms with which he must work; and in all such projects the frequent checking of the chromosome situation is important. In certain groups of plants, such as, for example, the grasses, sexual reproduction may be absent, the seeds being produced by some type of apomixis. The importance of advance information concerning such a situation must be obvious. New cytological techniques are continually being developed to meet such needs.

Reference should also be made to the use of improved statistical methods in the interpretation of plant breeding data, and to the value of applying statistics in the preliminary planning of such operations as comparative progeny tests as a basis for selection; see Fisher's "The Design of Experiments."[23] The recent work of Harrington[24] on the number of replicated small plot tests required in regional variety trials is a good illustration of the scientific solution of such a practical problem. Lack of time prevents more than this passing reference to a very important phase of recent progress in plant breeding.

In conclusion let me mention the importance of research as the basis for future progress in plant breeding, especially the significance of current research in the field of physiological genetics. It is safe to say that the relations between the chromosomes and the cytoplasm, on one hand, and the morphological and physiological characters of the plant, on the other hand, seem likely to be more clearly understood in the near future. New light on the genetics of size and of growth and form of the organism and its parts may lead to a better understanding of heterosis and to a more successful utilization of this phenomenon. Research on the genetics and physiology of development in plants is just getting under way, but it gives promise of future enlightenment which will have an important bearing on breeding for such qualities as yield, chemical composition and resistance to cold, drouth, diseases and pests. The artificial distinction between "pure" and "applied" research can no longer be maintained in general; it seems certain that henceforth scientific research on plants and scientifically practical plant breeding will go hand in hand in the service of society.

[23] R. A. Fisher, "The Design of Experiments," 252 pp. Edinburgh and London, 1935.

[24] J. B. Harrington, *Jour. Amer. Soc. Agron.*, 31: 287–299, 1939.

THE LAST EPIDEMIC OF YELLOW FEVER

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WITH mingled emotions of doubt and desire, we received the reports of the epochal experiments of Dr. Walter Reed and his notable associates on the field of Quemados in Cuba in 1900. When we were told that these remarkable men had demonstrated that yellow fever was conveyed only through the bite of a common house mosquito, then called Stegomyia, we were amazed and incredulous, yet longing to believe it were true. I recall vividly the conference with Chief Justice Albert H. Whitfield, of the State Supreme Court, soon after the results of the experiments were reported. As we sat on the porch on a fine spring afternoon, Justice Whitfield, from his wide knowledge and much wisdom, spoke of his experiences in several fever epidemics, his consultations with veteran physicians and his talks with intelligent men and women who had been in personal contact with the ravages of the disease. The apparent facts that he had gathered from these different sources made it difficult for him to accept the conclusions of the Army Commission of surgeons. At the conclusion of our conference he went slowly and thoughtfully down the walk, shaking his head in doubtful protest, and I imagined him soliloquizing: "Can it be possible that these epidemics of yellow fever which have ravaged the South again and again, closing the schools, eliminating railroad trains, shutting down factories, closing stores, depopulating cities and villages, paralyzing all activities and killing hundreds of people—can it be possible that all this has been brought upon us by a tiny, insignificant mosquito?"

We waited for further details of the experiments and for a practical demonstration of the conclusions of the commission. It came more quickly than we expected and with indisputable proof when Major Gorgas in 1901 exterminated the fever in midsummer from the city of Havana, a permanently endemic center of the disease. A few years later, if added proof were desired, it came again when the epidemic of 1905 in New Orleans was promptly abated and completely exterminated before the natural exterminator, the ever dependable frost, had come to do its work. Then we had to believe, and with what profound and grateful relief we accepted the verdict!

But the results of all this great work came after the epidemic of 1898. At that time we were firmly entrenched in our age-old belief in contamination from personal contact, from clothing and bedding used by fever victims and from other unknown, mysterious sources. The phase of the fever epidemics that frightened us most and was most responsible for the mad hysteria which always seized us was the inscrutable, utterly incomprehensible source from which infection came. "It was the mystery of its [fever] onset and the strange unaccountable manner of its propagation which chilled the heart and struck terror to the bravest." With this background, the epidemic of 1898 began its career and suddenly came upon us in late September in our quiet, peaceful college community in Mississippi.

"Both cases are genuine yellow fever. There will be a meeting at four o'clock in front of the secretary's office to decide what we are going to do." These were the words of the messenger, riding his wheel at full speed, and stopping at each house just long enough to deliver his message.

To those living in more northern lati-

tudes such a message could scarcely come, and its full portent could never be realized. But here in Mississippi, where frost before November is unusual, the herald left behind him men and women with pale, awe-stricken countenances, who knew not when or how this mysterious, deadly malady, "this pestilence that walketh in darkness," might strike them.

For forty-eight hours, since our local physician had divulged his suspicions and an expert diagnostician had been telegraphed for, we had met by twos and threes and fours, always with this question on our lips—"What were you going to do if the specialist pronounces it yellow fever?" Aye, there was the rub. What *were* we going to do? Had we been "exposed"? If so, then by going north to cooler latitudes, we would run the risk of almost certain death were we to "come down" with the fever. Could we get a special train to St. Louis or Chicago? We probably could, but we would certainly be locked within and not allowed to stop south of Cairo, Illinois. Besides, if some one should happen to be stricken with the fever in the closed car, all, according to the current belief, would become exposed and have to remain in quarantine for days in St. Louis in addition to running the risk of a "spell" of fever in a cool region. Later, the problem became further complicated because of a dinner party held two or three evenings before, one member of which had been taken to the infirmary, where his illness had been diagnosed by the expert, Dr. H. A. Gant, as a case of yellow fever. No doubt the onset of the fever began the day of the dinner. At least several now recalled that he looked languid and tired that evening. In the event that this was true, every one present must be regarded as a possible victim of infection and, therefore, a dangerous person with whom to associate. Who would care or scarcely dare to ride for eighteen hours in a closed railroad coach with these potential disseminators of this dreadful disease?

Dr. Gant's report of his inspection of the cases of illness at the college is of interest especially as it indicates the great fear of this dread disease. The people had gathered at the station to meet the "Special" which was bringing the expert, but they gave him a wide berth as though he might, in some mysterious way, be a source of danger. Dr. Gant says:

> As I stepped out of the coach, I noticed the people all gave way and allowed me a broad road to a horse and buggy being held by a negro man. Some one called to me, 'There is your buggy, Doctor,' and when I reached the negro he said, 'You just follow that buggy ahead of you, that man will lead you to the College.' General Stephen D. Lee was one of the noblest and bravest of men but when we met on the Campus, and I made the announcement of the fever, he turned pale and looked almost as if he would faint, such was his anxiety and distress.

The time was now past for argument concerning contagion versus non-contagion from personal contact. In this hour of hysteria, any commonly reputed way of "catching" the fever was accepted as a probability from which escape was to be provided at any cost. Why not go into the country and stay at a farmhouse for a few weeks? "You will have to face a shotgun first," grimly remarked our venerable professor of English. True enough. We had forgotten for the moment that in less than two hours after the telegram was sent for the specialist the campus had been surrounded by guards from the nearby town armed with shotguns and placed at intervals of one hundred yards, thus completely hemming us in from the outside world.

At four o'clock, we met in compliance with the messenger's notice. Some one had already definitely ascertained that a special train, with the restrictions before mentioned, would be furnished within twenty-four hours for those who wished to go to St. Louis. This necessitated, at least, a fifteen-hour ride mostly during the night, locked within an ordinary and crowded day coach with the added risk of all being exposed to the fever. But

men and women were panic-stricken. Reason had taken wings and had flown out of the window. All acted on the one idea of getting away and at once. The writer, never having had any experience with yellow fever and being unable to sense the great danger, chose to remain behind. From this distance in time and experience, it must be acknowledged that we were excellent exemplars of Pope's aphorism, "Fools rush in where angels fear to tread."

The decision was soon made and the request for the train put in at once. After the usual uncertainty and delay in matters of this kind, it was finally ascertained that the train would leave the village of Starkville, one and one-half miles distant, some time during the following afternoon. Fortunately, this branch of the Mobile and Ohio ran directly through the college grounds, a situation which forestalled any personal complications with the guards surrounding the campus. Since the final announcement of the train's schedule, there was left no more than time to bring together haphazardly the necessary articles for a month's absence. It was an occasion of frantic, bewildering haste, with homes and chattels left as they stood. Dwellings were left with doors unlocked, indeed, with some standing open as the occupants had rushed through and away. This was no time to think and plan for the care of the inanimate things left behind. The preservation of life was too absorbing to worry about material possessions.

Since this was to be the last train out and the last opportunity to communicate with our faraway friends and relatives, we wrote many hasty letters to be mailed in St. Louis by the courtesy of our departing neighbors. Years afterward, I saw one of the letters we had written. It was punched through with many jagged holes in preparation for the thorough fumigation it had received in St. Louis in accordance with the futile practices and regulations of the time. We who stayed behind were a trifle doubtful, but having made up our minds, it seemed weak and vacillating to change, so we watched the train disappear in the distance and returned courageously to our home. With the departure of the train, we realized that the campus had been the scene of a modern exodus. The empty houses, the lack of a familiar face or voice to greet us and the suddenly hushed activity had changed its aspect to that of a deserted village. Our emotions were many and mixed, not the least of which concerned the matter of life and death during the next few weeks.

The yellow fever special carried two day coaches, one for the inhabitants of the near-by village who wished to get away from all danger of the fever and one for the people of the college. Instructions had been issued by some official to lock the doors of the latter coach in order to prevent its passengers from wandering outside and exposing persons with whom they might possibly come in contact while enroute; but that perversity in human affairs which often upsets carefully made plans confused the orders and the town people were locked within their coach, while the supposedly dangerous college individuals were allowed their freedom. At the time it seemed the height of irony, but after the danger had passed it became the subject of much good-natured banter. It is fortunate that we can still look back upon our past predicaments with a refreshing sense of humor.

Probably no one except an occupant of the coach can ever adequately describe that night ride to St. Louis. The few individuals who had been guests two or three evenings before at the dinner party were a particularly disturbing element. Every one feared them, and although they were beloved neighbors a few days before, they were now objects of suspicion and fear to be shunned and set apart. It

was scarcely possible to get far from them in a coach where standing room only was to be had for some, and the floor, in the aisle, was crowded with sleeping children. A near and dear relative of one of the dinner party, with studied avoidance of her intimate kin, established her family at the opposite end of the car for such fancied protection as this short distance might afford. To such lengths will most of us go under the impelling stress of ignorant fear. The night was undoubtedly one of real terror to all of those old enough to realize the danger as the current knowledge depicted it. Every person looked at his neighbor with distrust and suspicion, expecting any moment to see the dreaded thing strike some one. Every known or suspicioned headache, every flushed cheek, every touch of nausea or evidence of faintness invoked a sudden fear and aroused an unreasoning emotion of imminent danger. Nor did this fear of each other end on leaving the train in St. Louis. There, each family went its own way to find rooms remote from former neighbors until the fruition period of possible infection had surely passed.

The campus was divided by the railroad into a north portion, the college proper and a south portion, a residential section; and, if my memory and coexistent notes serve accurately, we were the only family left on the south side. There were two other individuals of whom we shall speak later. Every family and individual were isolated and, in general, warned not to approach any nearer each other than fifty yards. This regulation was facilitated by the number of comfortable, empty houses available. Colored servants were plentiful in those days, but when we returned to our home from seeing the train away not one was in evidence—Aunt Emmeline, the cook, Eliza, the laundress, and Early Washington Livingston, boy-of-all-jobs, had melted away, vanished like the dew on a summer morning. They were wise, albeit fear was the basis of their wisdom. One belated colored man attempted to scale the fence too late and not obeying the command to halt, received a charge of small shot and lost an eye, but somehow eventually got by. We took this lesson to heart, for we knew then beyond the possibility of a doubt that the guards meant to carry out their instructions.

The two individuals living on our side of the campus were General Stephen D. Lee, president of the college, and W. H. Magruder, head of the department of English. In the area within the cordon of guards these men organized and directed all the activities and saw to it that the regulations were carried out to the minute. General Lee was a man slightly over six feet in height with a physique in full proportion. He was still every inch a soldier, with an austere, positive and sometimes domineering temperament, especially when excited. I recall a visit to his office when I found him pacing up and down the floor rehearsing a speech which he was to deliver later at the commencement exercises of the State College of Iowa. I had no more than crossed the threshold before he came at me like a lion and shaking his fist, exclaimed, "Sir, we had the argument, we had a right to secede and you had no right to coerce us." What little equanimity I might have had under normal conditions fled completely, and I stammered: "Yes, sir, General, no doubt, no doubt. You know, sir, I was born several years after the war and really, I–I know nothing about it." Immediately he smiled and became at once solicitous toward my request for funds for some small equipment to facilitate the work of the department over which I presided. Notwithstanding his stern demeanor he was as sympathetic and compassionate as a woman. This gentle quality of his character was evident in his tender care of an invalid wife and his loyal devotion to her through long, busy years. General

Lee will always occupy a warm and secure place in my affections for the sympathetic and loyal backing he gave to a young Yankee in the early years of his career.

W. H. Magruder was another intrepid soldier who still carried the scar of a bullet received through his cheek at Kenesaw Mountain, where he nearly gave "the last full measure of devotion" to the South from doing his part in an effort to stop Sherman's march to the sea. These two fearless men, compatriots in a devastating civil war, were now companions in a fight against a mysterious foe scarcely less destructive of human life. They were ably assisted by Dr. W. H. Barr, a calm forceful man with a delightfully dry wit, afraid of nothing and no one. He was continuously on duty, caring and prescribing for the sick, watching with an eagle eye over the well, directing the sanitary arrangements and finally, if need be, ready to assume the functions of an undertaker for those who might die. This faithful, enduring man cheered and inspired every one during those long anxious days. A good physician often becomes a great humanitarian.

The two old soldiers were rejuvenated and fired again with the martial spirit which had long lain dormant during years of civil duties. Both sat their horses well and every morning and evening they rode in company around the campus, and halting at some distance before each house, would halloo to the inmates. If we answered the call all was well, greetings were exchanged, inquiries after the patients were made, speculations regarding the probable time of the first frost were offered and they were gone until another day wore itself around. If perchance the occupants did not respond, it was understood that the doctor would be notified and we would be taken to the infirmary, where the fever would have to run its course. There was no sure escape from the disease except to run away from it. If one elected to stay with an epidemic he simply chose to take the serious risk of a chance infection.

Our first act was to ascertain whether he would be able to get food and supplies. We found that one grocery store in a village of three thousand inhabitants remained open, ready for service. Business was at a standstill—those stores whose proprietors had not already left found they might as well close and save the expense of upkeep; but the conditions in the village were not nearly as serious as they would have been had the fever actually been present among the inhabitants. Many towns in the state in which cases of fever were present were literally deserted during the danger period. It was arranged that the supplies from town should be delivered at the campus gate, from whence one of the guards would bring the packages one hundred and fifty yards inside and then retire, allowing us to come forward and get them. It soon transpired, however, that a fearless employee of the college was willing to gather up the food and distribute it by leaving the packages at a very respectful distance in front of each occupied house, where we could get them with little trouble and without danger of coming in contact with any one. A little later we were notified that milk and butter would be furnished gratis from the college farm. Milk we had, for one of our neighbors had left his cow in our care and we were pasturing it in our other neighbor's lot, while our horse was turned out to the common. It will be noted that "horse and buggy days" could be real interesting.

During the first few days of the siege it seemed that we were perforce to become vegetarians, for the source of our meat supply had vanished, but we had not realized the resources of a college farm. We were most agreeably surprised to receive early notice that meat from animals slaughtered on the farm would be furnished at frequent intervals. Still later came an order informing us that small

quantities of vegetables from the grounds of the horticultural department would be distributed daily. No center of infection during this state-wide epidemic could have been as favorably situated as we were in this limited area. Certainly we had never before and have never since lived with less personal expense than during that long month of waiting. We had little thought, however, for that phase of our existence. Indeed, the social and economic ills of the world were forgotten for the moment, a happy compensation for our many anxieties.

When people are confined within a definite enclosure knowing there is no chance of getting out for weeks, even a half-acre lot becomes small and monotonous. The enforced absence from technical books and the laboratory irked, perhaps, the most, although not as profoundly as it would have in later years when these tools became more vital elements in my life and work. We made as much as possible of the household duties, and happily there were no restrictions on thinking. It was a grand opportunity, if one could forget the implications and dangers of the situation, to think and plan for the future. We had the assurance that nature would eventually rescue us if we were fortunate enough to escape the mysterious sources from which the fever came. Why or how the friendly, hoary frost eliminated the disease no one knew—that it did, however, was a well-known and thoroughly established fact. Had we known that the Stegomyia mosquito became inactive at temperatures below 60° F. and that it quickly died at temperatures below 40°, it would have had no meaning for us. We should have regarded it simply as an interesting bit of knowledge wrought out of the biological world by an inquisitive genius bent on prying into the secrets of living things. The baffling mysteries which surrounded yellow fever previous to the discoveries of the Reed Commission seem to-day almost incredible. Dr. G. Farrar Patton remarks, "Nowhere in the history of scientific research is there a more conspicuous instance of the tenacity with which nature seems to guard her secrets than in the long and deadly struggle it cost mankind to wrest from her the secret, so priceless yet so simple when discovered, of the causation of yellow fever." The Stegomyias hummed merrily around us, but we knew nothing of their potentially dangerous qualities—they were merely annoying mosquitoes, nothing more. The individuals with which we came in contact were certainly uninfected with the causative organism of the fever. None of the mosquitoes carrying infection reached our end of the campus or, if they did, they failed to reach us.

Experience had shown that during an epidemic of yellow fever a certain percentage of the cases would terminate fatally. Therefore, General Lee, with his penchant for organization, notified the few unmarried instructors who had chosen to remain on the campus, that they would meet the next morning to go over the adjacent field with the worthy purpose of selecting a site for the burial of any chance victims of the fever. It is one thing for a young man to select a lot in a cemetery in which he may rest in the dim, distant future and quite another matter to choose a site for a grave in which he may lie within the week. The doleful, anxious countenances, the lagging footsteps and the total lack of enthusiasm for the expedition were painfully evident, especially in the face of the general's cheerful enjoyment of another opportunity for organization. The crest of a ridge in an open field just east of the campus was chosen with little argument, and they hurried away from the grim business. The incident gave the General a fine opportunity to chaff the young men for their apparent lack of those qualities of stern courage which he maintained should characterize a soldier

under fire. Happily, not one of the nine officially reported cases of fever proved fatal, and the emergency burial field remains still unoccupied.

This zero mortality was undoubtedly due, in large part, to the constant attention and skilful treatment given the patients by Dr. Barr, to the care of the faithful nurse in attendance and to the excellent facilities of the college infirmary. Available statistics from twenty-seven cities and villages in the state report a total of 747 recognized cases of fever, with a death list of 51, a mortality of slightly less than 7 per cent.

How anxiously we watched and waited for an early frost. We noted the furry Isabellas scurrying along in quest of winter retreats and recalled the old saying, "hurrying caterpillars and an early fall," hoped and prayed it might be so, and it was so. It came during early November, and had we been pagans we would certainly have elevated frost to the status of a god and held a festival in his honor. One could feel the great shout of relief and joy throughout the land. The twinkling fires of the guards died out, the shivering men hurried home to their own firesides, the exiles returned, normal activities began, the college opened on the 15th of November, and the last wide epidemic of yellow fever was at an end.

It was a few days over two years, however, before we knew that never again were we to pass through a similar experience. Late in the evening of December 31st of the year 1900 Walter Reed from the Barracks in Quemados, Cuba, wrote to his wife in Baltimore:

> Only ten minutes of the old century remain. Here I have been sitting reading that most wonderful book, "La Roche on Yellow Fever," written in 1853. Forty-seven years later it has been permitted to me and my assistants to lift the impenetrable veil that has surrounded the causation of this most dreadful pest of humanity and to put it on a rational and scientific basis. I thank God that this has been accomplished during the latter days of the old century. May its cure be wrought in the early days of the new! The prayer that has been mine for twenty years, that I might be permitted in some way at some time to do something to alleviate human suffering has been granted! A thousand Happy New Years! . . . Hark, there go the twenty-four buglers in concert, all sounding "Taps" for the old year.

History holds many lessons for us, and it may be well to have recalled something of the suffering and economic losses caused by past epidemics of yellow fever, although it is improbable, thanks to our knowledge of the epidemiology of the disease, that this country will ever suffer again from its ravages. During the years following Reed's discovery, the work of eliminating the fever from this country went along rapidly and successfully. By 1927 it was thought that the disease had been practically eradicated from the Western Hemisphere. Then suddenly a most perplexing situation arose—urban epidemics of the fever developed in certain South American cities. Again, the matter was clouded with mystery. From whence came the infection? Where and what was the source from which the virus came that started these epidemics? Fortunately, we have in this country a marvelous institution ready and eager to engage in an effort to solve the difficult problems affecting the physical ills of mankind. The Rockefeller Foundation, the watchdog of the ills of humanity and probably the greatest single independent agent for the amelioration of those ills, began an investigation at once. An intensive survey disclosed that vast areas of the hinterland of South America are endemic centers of "jungle yellow fever" in regions where *no Stegomyia mosquitoes* exist. These rural reservoirs of permanent infection serve as a source from which the fever is carried into densely populated areas of cities inhabited by Stegomyia and an epidemic ensues. Surprisingly enough, additional species of mosquitoes, other than Stegomyia, in the jungle areas have been incriminated as

"natural vectors of yellow fever." Thus the problem involving this disease has again become complex and greatly broadened in its aspect. One naturally inquires regarding the significance of this new development for the United States.

It is hard to realize that instead of a distance measured by a voyage of a week or more, we are now within a flight of hours from the cities of South America; and as Dr. V. G. Heiser says, "A mosquito loves to ride in an airplane as much as a dog does in an automobile. Open a door a crack to either one and he or she will hop in." Unquestionably mosquitoes are capable of riding for many hours in an airplane and arriving at a landing field in an active, lively condition. Moreover, infected mosquitoes are probably just as eager and able to ride in an airplane as uninfected ones. It therefore seems not at all impossible for yellow fever to be reintroduced into this country.

We must not forget, however, that Walter Reed and his associates have lifted the impenetrable veil surrounding this disease and have "put it on a rational and scientific basis." As a result, the prophylactic measures that have been developed for the control of the fever indicate, with some degree of assurance, even though infected mosquitoes may be brought to this country in airplanes and though the insects may bite non-immunes, thus initiating sporadic cases of the fever, that it is highly improbable for a *widespread epidemic* of the disease ever to develop again in the United States. This assurance, however, should not, for a moment, cause any relaxing of our attitude of watchfulness regarding the reentry of the fever into any locality in this country. Physicians in southern areas, especially, should always keep familiar with the symptoms of the disease and be able to diagnose a sporadic case or, at least, to become sufficiently suspicious of the case to isolate it at once, thoroughly screened from any possible access by mosquitoes. The fact that the virus of the fever can be carried from a stricken individual *only by a mosquito* still holds the problem within the limits of reasonable assurance of control.

THE RURAL COMMUNITY AS A SCIENCE LABORATORY FOR CITY CHILDREN

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SCIENCE plays an ever-increasing role in shaping human lives. As man has learned to use power-driven machinery in producing food and other raw materials a larger and larger proportion of the population has been freed for other activities. Mass production of standardized goods by power-operated machines coupled with the rapid evolution of transportation have hastened migration to large cities where individuals are more and more dependent upon others for the goods and services they receive. Each new scientific discovery seemingly adds impetus toward specialization, standardization and remoteness of consumer from the production of the goods he uses.

Urban students have little opportunity to participate in experiences familiar to most rural boys and girls. Of course, city children do have many unique opportunities for the study of science in museums, in zoos and in botanical gardens. They also have closer contact than rural children with large-scale construction work, manufacturing establishments and advanced means of transportation.

Rural children, however, can learn much science through participation in such farm activities as caring for the farm water supply, furnishing heat for the house, maintaining sanitation, controlling insect pests, draining and cultivating the soil, growing, harvesting and storing crops, feeding and caring for animals, constructing and repairing farm buildings, using simple tools, operating farm machinery and the curing of meats for the family. Needless to say, these experiences must be pointed up for most children.

Both public and private schools are endeavoring to furnish concrete vital experiences like those mentioned above. Some have a farm school, some a school farm, some a school forest, some a school camp, and others plan short week-end trips to the country. This paper describes the science aspects of the rural study trips conducted by the Lincoln School of Teachers College for its ninth grade during the past two years. The second year the Alfred P. Sloan Foundation financed these trips. The social science aspects of one of these rural trips and other school trips are reported in two recent articles.[1,2]

Early during the 1936 school year ninth grade pupils and teachers felt the need of first-hand experiences in vivifying the theme of their integrated course, "Living in a Machine Age." A plan was presented to the parents. They agreed to finance a week's study in a farming region in western Massachusetts, so both pupils and teachers of the ninth grade moved to and lived for a week in the homes of local families in a rural Massachusetts town. Upon arrival at their destination some discussion around the fireside was essential to familiarize the boys and girls with kerosene lamps and lanterns and the hazards that accompany their use, with sources of drinking water and with the location of wash-rooms and toilet facilities. They needed to plan for their share in the preparation of the following day's meals, their responsibility in

[1] Alice Stewart, *Teachers College Record*, 39: 494–505, March, 1938.

[2] Elmina Lucke, *Progressive Education*, 15: 617–628, December, 1938.

UNLOADING FUEL SLABS

caring for their own beds, and their cooperative effort in keeping the bedrooms, wash-rooms and toilets in a sanitary condition. Because the farms were located near state forests and because the nearest neighbors were about a half mile distant, pupils were cautioned against getting lost.

In this environment opportunity was provided for all the pupils and teachers to participate in varied activities common to rural youth. These city students also took short trips to study the natural environment and local industries. The problem of soil conservation and flood control was dealt with in a visit to a local reservoir and to a lumber mill operating in a nearby woods. The problems related to general and specialized farming were met in trips to neighboring farms. The problem of the relation of industry to its natural environment was seen in a visit to a granite quarry and to a paper mill. The problem of the maintenance of health was faced in a visit to the country doctor and to the County Health Center.

In the country heat doesn't just come in steam radiators. Fires must be stoked. This requires fuel, and limited supplies on hand must be replenished. So a local truck and the farm car and trailer were used in hauling slabs.

Barbara summed up the experience this way:

> We bumped up a double rut to a clearing where the wood was strewn around in piles and started a double lineup. Some cooperation! I personally didn't do much work but I can't say the same for everyone else. They all worked away for an hour or so passing planks along to me and the truck. When we quit the truck was piled and then we got on top. Coming home was a mechanical elephant ride and we were hours late for dinner. Maybe work is only F × D but it certainly is exhausting.

This experience lasted long enough for boys and girls to learn to work together, to use the laws of inertia effectively, and to work in rhythm. They got the thrill of achievement in learning to use their bodies efficiently and in cooperating with others doing a like task. The fact that they hauled eleven cords of wood during the day testifies to their intelligent participation and appreciation of the way a job can be done cooperatively on a farm.

Since all could not share in hauling slabs at one time, a second group went to visit the nearest farm, a self-sufficient venture of two bachelors, and a third group collected apples for cider making.

At discussion time the group that had visited the farm shared their discoveries. They talked of butchering and curing meats, of making bread, butter, cheese, jellies, sauerkraut, of keeping vegetables over the winter and of preserving eatables in summer in a cellar refrigerator. Taxes, home-made clothes, renting the right to pick berries, selling milk and feeding hunters in the winter time—all these items and many others opened up new vistas of economies for our urban boys and girls.

The group that had gathered apples made cider from them. Experience in studying and operating the hand mill enabled them to see how a train of gears was used to gain speed for the fly wheel, how the inertia of the flywheel kept the mill going evenly and how the application of a small force at the end of a long lever to the worm gear of the press exerted a tremendous force on the apple pulp.

Muggy said this with regard to the cider making:

> At first we made only one gallon per bushel. Then we were told to use a burlap bag (in the press, which we did), and got almost two gallons per bushel. The cider was marvelous. We made eight gallons and drank some of it at the barn dance the next night.

The second step in the preparation of the fuel was the cutting into short lengths with a buzz saw. Power was secured from a farm truck by replacing one rear wheel with a belt pulley. The pupils helped set up the machinery, handled slabs, and piled the cut pieces in the wood shed.

The following evening's discussion centered around the use of inertia in work. Examples given were the throwing of wood from one to another, the momentum of the fly wheel on the cider mill, and the use of inertia in lifting wood from the slab pile. One girl mentioned the gain in momentum when cycling down

MAKING CIDER

NAILING BATTENS ON THE GARAGE

hill and the necessity of using the engine as a brake when going down grade with a heavy load.

The use of the transmission gears when hauling heavy loads up hill was discussed. Some one raised the question of why both rear wheels of the car did not turn when buzzing wood. This focused attention on the car differential. Fortunately, there was an old one in the barn which some of the group decided to take apart. Shortness of time prevented their completing this project while on the trip. Later in the classroom they demonstrated the differential so well that the entire class achieved a good understanding of its operation.

There were queries of why the belt was twisted between the pulleys, how hard the Ford engine was working when the saw was attached to it, and why the belt came off when a large slab was sawed rapidly. Discussion ensued on how to set up the buzz saw and how to use the first-class lever in lining up the car wheel and the saw wheel. Conclusions were drawn that rhythm in work is really an application of inertia, and that farm life offers many possibilities for groups to work together in a rather unique way.

Some conception of the varied types of activities involving scientific principles, as well as an appraisal of the learning taking place, can be gathered from the following comments taken from pupil notebooks.

Paula:

At Heather Hill Farm there were a number of things going on and I decided to do some carpentering on a floor upstairs in the barn. This was grand fun and gave me a feeling of satisfaction when I nailed a board down successfully or sawed a board straight. It was hard work, but made me work up an appetite for the good supper we had.

Ralph:

In the afternoon I did a little painting on the garage. Then it started to rain so I gave that up. I then went in the barn and helped two others put up the second story in the barn. We worked on that most of the afternoon and finally finished. Finishing made me feel pretty good.

Maressa:

We painted the garage after the batons were on. We wrecked the chicken coop and handled wood for the saw. In other words we really worked.

Ken:

In wrecking the chicken coop I used a lever with which I was able to pry out nails, lift the whole roof, and move the roof off the walls. . . . A good example of the variation of the moment of force was that I was able to remove spikes with my wrecking bar which could not be removed with a short handled hammer. Later in the morning when I switched to sawing, I saw that the truck had been jacked up by means of another first class lever.

Howard:

As Mr. C . . . . didn't feel very well we did some of his work. We actually enjoyed hauling water, feeding a pig and getting and piling wood, after which we settled down to our notes.

The group also had experience in the provision and preservation of food for the winter. They observed the butchering of a pig, made sausage, prepared ham and bacon, rendered lard, and made soap. Pupil notebooks again tell the story.

Ruth:

Boiling water was poured into a huge wooden tub. In this the pig was placed by means of a pulley. Then lye was poured completely over it. Again the pig was dipped in boiling water and taken out to be scraped perfectly clean. The pig was then hung vertically and slit neatly down the middle. The liver was inspected by a government inspector and found to have an inflammation, but we were told that the rest of the meat was still edible. The pig was thoroly cleaned and left to hang stiffly in the barn. In a day or so it was cut into the following pieces: ham, fat back, loin, bacon, spareribs, picnic shoulders, clear plate, Boston butt, fore shank, and jowl.

Henry:

I saw where they got the pork chops and also where they got the bacon. I never knew they could get so much out of a pig.

Kenneth:

Note how a tripod of three two by fours was made to hold up an end of the pole supporting the kettle. In order to lift the pig easily so that it could be put in the lye water, a block and tackle with a mechanical advantage of four had been hung from the rafters. In this way a force of 37.5 pounds could lift a 150 pound pig.

Short trips were taken to neighboring farms. Here pupils saw how farmers kept their animals warm and clean, and how they fed cattle and chickens scientifically. They noted the use of sawdust for insulation around houses, the storage of food in cellars, the convenient arrangement of farm buildings, and the use of various mechanical devices such as washing machines and cream separators.

A visit was made to a modern Ayrshire dairy farm which produces and retails 300 quarts of milk daily. Scientific farming was studied here. Pupils saw the caterpillar tractor at work. They observed the use of bottling, cooling and

BOILING WATER FOR USE IN BUTCHERING

GROUP WITH TRACTOR

pasteurization equipment. They gained some understanding of the adaptation of Ayrshire cattle to hill regions, the use of hay and ensilage as roughage, the endless process of bookkeeping with a registered herd, the hazards of large-scale production and the meaning of the saying, "The value of the herd sire is half that of the herd."

With regard to the trip to a local granite quarry one pupil wrote:

> There were two points that stood out as most interesting. They were: the very simple machines used in all of the processes and the fact that you see the granite as it is in the earth and then all of the processes right then and there until it is shipped to be used as tombstones.

At a local woods lumber mill the pupils saw the whole process from felling and hauling trees to the sawing of rough lumber. The owner of the mill, an experienced lumber man whose eyes still light up when he surveys an especially fine tree, enjoyed answering the many eager questions. Calculations were made on one tree, determining the cost of felling, hauling, sawing and trucking it to the highway. There was time to see how each part of the activity was carried on, how the logs were moved on to the carriage, how the carriage was made to go forward and back, how the width of board was determined, how sawdust was blown away, and how board-feet were measured and tallied.

Much learning about the relation of trees to soil, flood control and future prosperity was evidenced by pupils in their discussion of the trip.

Margaret comments:

> As we walked thru the woods we saw a great change in the trees. On our side of the fence there was rich black soil filled with leaf mold. Water was plentiful and the smell of decaying and damp leaves was strong. Many varieties of mosses and berries grew, such as gold thread,

star moss, travelling and shining club moss, stag moss, laurel, winterberry, and wintergreen. On the other side of the fence there wasn't a tree over two inches in diameter. The ground was not as fertile and the trees were thin, anemic, and a scrubby third or fourth growth. The comparison between the lumbered and the virgin (or relatively so) forests, shows the vital importance of reforestation. As an example the mill started in a rich hemlock grove. Now they are chopping down tree after tree, young, old, fat, thin, tall or short as long as it makes lumber. What will be left of the beautiful hemlock grove? Only a tragic procession of neatly cut stumps will remain to mark the spot. Years will roll by, the land, open to wind and water erosion, will be swept by floods and droughts. What will become of our green hills? With the trees cut down the soil will be washed away and the towns drowned. Trees prevent floods and erosion by controlling the water and holding the soil together. The roots hold the soil and keep it from being washed away. The leaves fall and stimulate plant growth and protect the roots in winter.

That it is impossible to distinguish clearly between scientific values and social science values when appraising these experiences is shown by two pupils in their attempt to express their reactions to rural study.

Robert:

The week was an experience that I shall never forget. It not only showed how rural life compares with urban life, but it also brought me very close to the people. I wondered when I visited at various places whether the native children realized how much experience they were actually getting by living where they could do work. The older people were willing to stay on farms and barely exist. The younger people, however, were discontented with that type of life. They wanted more out of life and felt that they could earn more money and buy more privileges and luxuries by going to large cities or working in factories that were invading the countryside.

Eleanor made this appraisal:

I think I could write a book on everything that happened and everything I saw and learned during the week of studying rural life. Incidents and things like—the stage that brought the milk, mail, and groceries, the wonderful apples

GROUP AT LUMBER MILL

that you could eat all day, how we pumped water, heating water when you needed it, the building of the fires in the morning in contrast to turning on the radiator in a steam heated apartment, bringing in wood and keeping the fires going, using the lamps instead of electric lights, contacts with people in the community, the stories about buildings, farms, and towns, our discussions, our evenings together, the barn dance—the perfect party evening—the varied activities inside and outside, making bread and nailing slats on the garage, the cider press and how it worked, the mechanical advantage of 720 and the pressure of ten tons applied to squeeze the apples, the animals we saw with the complications of caring for them, our surroundings, the beauty of the valleys and the hills, what our houses and rooms were like, the little window by my bed where every morning I could look out and see the dawning day, the contrasting types of people we met. Such incidents as these and many others I think will remain with us for years to come. We now have a realistic idea of rural life which could not be found any other way. We worked and played together and got to know each other and that's what made the trip a success. We really were one large family.

The enthusiasm of all the pupils and their parents for these experiences indicated their worth. Several pupil-initiated projects grew out of these rural studies. One group of pupils secured, dismantled and later ran an automobile engine. One group continued work on the curing and canning of meats. Some pupils investigated the work of hospital clinics and of settlements. Some studied the soil and forest conservation work of the United States government. Others constructed working models of water wheels and of a lumber mill. The intelligent interests of the pupils attest the values they received from rural study. The entire class work throughout the remainder of the year was definitely motivated. Pupils continually compared and contrasted their in-the-city experiences with those they had had in the country. These urban boys and girls had gained a better understanding of how science functions in their daily lives.

THE PAN AMERICAN HIGHWAY. II.

By HERBERT C. LANKS
MEXICO CITY, MEXICO

GUATEMALA

GUATEMALA is a land of many wonders, steep ascents and descents, volcanoes and volcanic lakes, quaint and picturesque people and the remains of the oldest civilization on this continent. Although Guatemala has a fringe of low-lying, tropical, coastal plain around the higher central plateau, the latter is the cool high Guatemala we think of. Most Indian of all the Central American countries, it has preserved the primitive, picturesque dress of centuries ago.

Guatemala has probably a greater network of highways in proportion to its size than any other Latin American country. Although not generally paved, they are passable and make the various parts of the country accessible to each other all seasons of the year. The very economic life of the country is based on these highways for Guatemala is a coffee country. Since it is too rugged for railways, highways are necessary for getting out the coffee. Every adult male in the country must bear his burden of highway construction financially or by physical labor to the equivalent of two week's work a year.

After crossing the Mexican frontier near Malacatan, the Pan American route climbs in very steep ascents to the eight thousand foot elevation of San Marcos. Neatly paved streets and orderly rows of adobe-walled and red tile-roofed houses characterize such old Indian villages and towns. Neatness and orderliness characterize Guatemala internally and externally in contrast with her Latin American neighbors. Up in this cool, elevated plateau it becomes uncomfortably chilly at night. Even during the day in the shade at this altitude one feels quite chilly.

Along any of the highland roads, land is cultivated on very steep inclines. One wonders how the patient cultivator of the soil maintains his foothold on land with such a precipitous slope. Moisture is furnished often by the light precipitation from the clouds which rest on these steep slopes. Where cultivated fields do not yet take the place of the dense, virgin forest we find in the latter strange and exotic plants. Enormous ferns that seem to belong more to the carboniferous period, wild orchids, gigantic Guanacaste and Ceiba trees, all growing together in an impenetrable jungle, color the exotic scenery along the highland roads of Guatemala. Such is the road with its very steep ascents and descents on the Quezaltenango, second largest city of the country.

One of the interesting side trips for the tourist off the Pan American Highway route is to Chicicastenango, heart of the Quiche-Mayan Indian country. There are many other interesting Indian centers as Totonicapan, Momostenango, Solola and other places. However, market day on Thursdays at Chichicastenango is one of the largest and most picturesque. Also, it is here that the Indians perpetuate a quaint ancient ritual of burning of copal incense in front of and in the Christian churches. The floors of the churches at Chichicastenango are slippery with the wax of lighted candles placed on the floor leading from the entrance to the altar. Flower petals, pine needles and other votive offerings are similarly placed, quaint remnants of a pagan culture of bygone days.

Perhaps as picturesque as anything is the religious procession occurring on almost any saint's day when the image of a saint is carried through the streets on the

THE PAN AMERICAN HIGHWAY

WINDS TORTUOUSLY UP INTO THE MISTY MOUNTAINS TO QUEZALTENANGO IN GUATEMALA. NOTE GIGANTIC TREE FERNS STANDING IN CULTIVATED FIELD AT THE LEFT.

shoulders of men or women to the accompaniment of beating drums and shrill fifes with sky-rockets and bombs to accentuate the occasion. Besides a most interesting Indian life, the tremendous ascents and descents to highway altitudes above ten thousand feet, the towering volcanic cones, the strange and exotic vegetation and the beautiful emerald blue lakes supply an infinite variety of scenery of unsurpassed beauty and awesome grandeur.

The highway crosses the country to the capital from Quezaltenango by several routes, one leading around the beautiful Lake Atitlan. Nestled in the folds of the bold mountain slopes which surround this famous lake are Indian villages named after the twelve apostles, some of them only accessible by boat from the lake. The highway climbs and twists to the high altitudes surrounding the lake, glimpses of which become suddenly visible through the clouds far below as the motor car swings dizzily around the points leading up to the plateau above.

The bleak high altitudes at some points on the road to the capital become uncomfortably cold. At length a glorious sight is glimpsed through the pass by which the highway descends to a great valley of warmer climate and greener appearance. The sun is reflected on the distant white buildings of a gem set in verdant green setting. A welcome sight is this most modern capital city of a country that is essentially primitive in culture. All these countries have their contrasts, but Guatemala probably excels in contrasts, with its most primitive of indigenes and most modern of capitals. The modernity of its capital is due to the fact that earthquakes have played such a part in shifting Guatemala capitals to new sites. Many of the present city's buildings date from the earthquake of 1918. The site of the old colonial capital destroyed by earthquake in 1776, now called Antiqua, is worth a visit. Here are seen excellently preserved ruins of the massive structures when the capital city was one of the cultural centers of the new world.

To-day Guatemala City is clean, peaceful, quiet and modern, in fact, modernistic in parts. The shops, for the most part, would grace any American city. Fine movie houses show late run American and other photoplays. There is not the same hustle and bustle of streams of traffic here as in other Central American metropoli of the same size.

El Salvador

Salvador is the smallest and the most densely populated (three times the population density of the United States) country of Central America. It has the distinction of being the only republic north of Panama which does not touch two oceans, for it lies entirely on the Pacific side. It is served by the most and the best roads of all Central American countries, being traversed nearly the entire length by a modern paved highway.

With the exception of Guatemala, Salvador is the only other Central American country that has transportation across its frontier into another country, and that country is Guatemala. From the latter country, Salvador can be entered by highway or railway, although this has only been possible in the past several years. The railway from Salvador across the Guatemalan border was built more to reach the Guatemalan point of Barrios on the Atlantic side, rather than for transportation into Guatemala. As a matter of fact, the Central American countries have little commercial intercourse with one other. Their foreign trade is with other and remote countries, primarily because their exports are similar.

The two hundred miles across the country of Salvador are an interesting stretch of the Pan American Highway. The first large place in Salvador out of Guatemala is Santa Ana, of about 80,000 population, a center for the cultivation of high-grade coffee. It is only 48 miles from the capital, San Salvador, reached by paved road which is part of the international route. Roads and railway lead out from Santa Ana to various points of interest, including several of the lakes which make Salvador's scenery so interesting. Only a few hours south by highway near Sonsonate is the famous Mount Ixalco, which is constantly active. It is referred to as the "Beacon of the Pacific," because its red glow is visible

GUICHE-MAYAN MAIDEN WEAVING ON THE HAND LOOM OF HER ANCESTORS.

INDIAN WOMEN AND CHILDREN ON A WELL-PAVED STREET IN GUATEMALA.
EVEN LITTLE CHILDREN ADOPT THE CUSTOMS AND DRESS OF ADULTS.

A YOUNG INDIAN GIRL ALONG THE WAYSIDE IN GUATEMALA
CALMLY UNDOES HER BURDEN AND PREPARES HER MEAL

at night far out on the Pacific. The highway from Santa Ana to the capital passes through Santa Tecla, where one can visit the huge crater within a crater.

San Salvador is the capital city of about 100,000 population. Its elevation of 2,000 feet gives it a semi-tropical climate, warm, but not unpleasant. It is a modern city with a style of architecture that would suffer least damage from earthquakes. It has beautiful parks with luxuriant tropical plants and blooms. Considerable English is spoken in the capital and Americans are most warmly received. The democratic nature of the people makes them seem to have much in common with Americans.

The highway from the capital southeast to the border of Honduras is about completed as far as San Miguel, which is only 25 miles from the border. The country is rolling from the capital southward, with ascents and descents, although nothing like the ascent to the high central plateaus of Mexico, Guatemala and Costa Rica. The road passes through a coffee country noted for its beautiful scenery. There are rivers, lakes and tropical landscapes offering constant variety to the scenery enroute. The large Lempa River, at present, is crossed by ferry. Along the coast are found the only extensive forests of Peruvian balsam in the world. Near San Miguel to the south, the highway passes through some extensive fields of henquen, or sisal fiber.

The Pan American Highway leaves San Miguel somewhat to the northeastward, and crosses the Guascoran River, which is the frontier between Salvador and Honduras, near Santa Rosa. This stretch of the international route is as yet not much more than a dirt trail, passable only in the dry season.

Honduras

Less than 100 miles of the Pan American Highway passes through Honduras. It is the only country through whose capital the international route does not pass, because to do so would require a considerable detour. There is, however, a branch that leads from San Lorenzo up to

THE CHURCH OF AMAPALA
PERCHED ON A HILL OVERLOOKING THE TOWN.

MOTHER AND CHILD IN GUATEMALA.

A MULETEER SECURES HIS LOAD.

the capital, Tegucigalpa. The route of the Pan American Highway crosses the Guascoran River near El Aceituno and from thence continues to San Lorenzo and to Choluteco. At the latter place, a very fine bridge contributed by the United States crosses the river. Only earth-roads exist to these places, possibly passable with great difficulty by motor in the dry season. From Choluteca, which is not very far from the Nicaraguan border, the route crosses a slightly developed region into the region of Esteli of Nicaragua, which is just as slightly developed.

Honduras is the third largest of the Central American republics with about a million population, very slightly connected by any means of transportation. The country is mountainous, abounding in minerals and richly timbered but very little developed. Relatively speaking, Honduras depends more upon air transportation than any other Central country. Tegucigalpa has the best aviation field in Central America, well served by two large air lines, Pan American Grace and Taca.

A good deal of Honduras is unexploited and even unexplored. Probably no Central American country could profit more from the coming of a modern highway. At present it is easier to go around the short stretch of highway through Honduras by means of a motor launch across the Gulf of Fonseca into Nicaragua. From the port of Moragan it is but a short distance by rail or horseback to Chinandega, which is the first large place on the old route of the Pan American Highway in Nicaragua. The train parallels the route up to the capital, Managua. Because of this fact the international route has been changed at the request of the Nicaraguan government to approach the capital from the east of Lake Managua.

Nicaragua

The Pan American Highway has been re-routed through northern Nicaragua. Formerly it passed west and south of

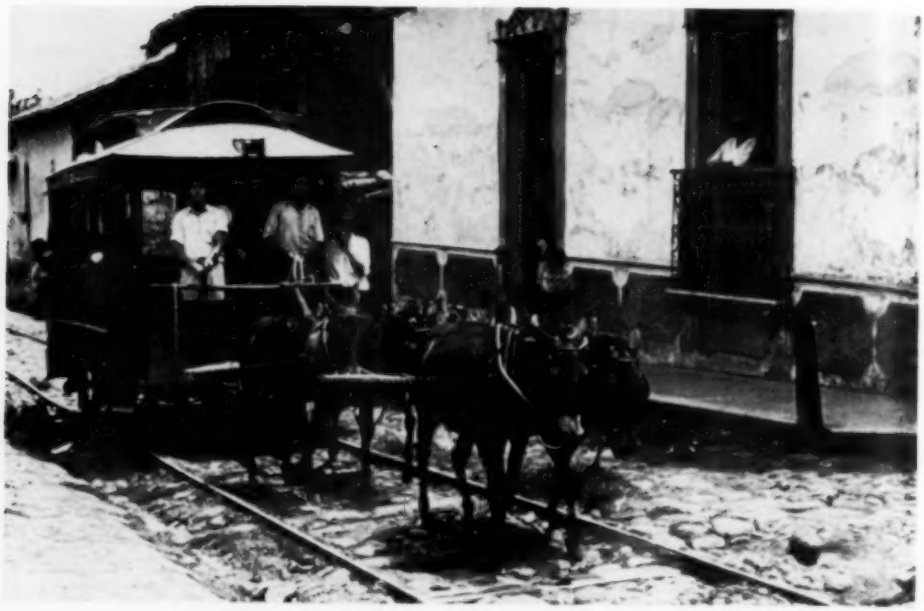
Lake Managua, but now passes between Lake Nicaragua and Lake Managua, to the east of the latter. This takes the international route through a large undeveloped region in Nicaragua centering around Matagalpa. The original route skirted the Gulf of Fonseca and paralleled the railway from Chinandega to the capital, Managua. Since this region was already served by this railroad, it was thought by the Government of Nicaragua that the projected highway would do better to serve the rich but little developed region further inland.

From Managua the highway reaches the old colonial city of Granada, on Lake Nicaragua, follows more or less the western edge of the lake over fairly level country to Rivas, approaching the border of Costa Rica. As the latter border is neared, the country becomes rougher and more rugged, as is typical of Costa Rican topography.

Very little of this route through Nicaragua described above is finished highway. Leading out of the capital, improved road is being pushed into surrounding country. This is the general story of highway development in all these countries. Generally speaking, the capital is the economic, as well as the political, capital. Hence, highway development in most of these countries develops first as a series of roads leading from the capital to centers which serve and are served by the capital. At present the highway in Nicaragua is being most actively pushed northward between the lakes toward the border of Honduras into the Matagalpa section. Its furthest extent at present is about 40 miles up to the Maderas bridge, which is a gift of the United States to this country. A very rough all-weather road reaches as far as Esteli toward the Honduran border.

Nicaragua is the largest Central American country and the most sparsely populated at the same time. Crossed by two heavy mountain ranges the country is considerably broken up in topography with also resultant climatic differences.

THE PAN AMERICAN HIGHWAY ALONG LAKE ATITLAN.
PRESENTING A MOST PICTURESQUE SIGHT WITH THE VOLCANO OF SANTA MARIA IN THE BACKGROUND.



A HORSE-CAR IN A VILLAGE IN SALVADOR

THE CHARM OF VISITING THESE COUNTRIES LIES IN THE FACT THAT ONE STEPS BACKWARD A COUPLE OF GENERATIONS IN SOME THINGS SUCH AS THIS, A CENTURY OR TWO INTO COLONIAL ARCHITECTURE AND CUSTOMS, AND A MILLENNIUM IN ANCIENT INDIAN ARCHEOLOGICAL RUINS.

NATIVES FROM THE COUNTRY SELLING FOOD IN TEGUCIGALPA, HONDURAS.

Very large sections are absolutely undeveloped and even little known. Like all Central American countries, the large population centers are on the Pacific side, much of the area of which is occupied by the large lakes Managua and Nicaragua. The latter comprises part of the route of the proposed Nicaraguan canal, the rights of which are owned by the United States through a treaty of 1916. Wonderfully fertile regions, both valley and plateau, would be thrown open for use if Nicaragua could develop any system of transportation.

AN AERIAL VIEW OF TEGUCIGALPA, CAPITAL OF HONDURAS.

Costa Rica

At present, the Pan American Highway route is most impassable in Costa Rica because of the extreme ruggedness of the terrain and the sparse population. In addition to the broken topography with very high altitudes, the international route crosses sixty streams that will have to be bridged. It is very unlikely that the Costa Ricans will be able to complete their stretch of the highway in the near future without some outside assistance. With regard to highway development, especially along the international route, Costa Rica repeats the same story as do the other countries, that is, a system of highways reaching out from the capital. Only about 50 miles of Costa Rica's 356 miles of the Pan American Highway are at present paved. The 163 miles from the Nicaraguan border to Naranjo is but dirt trail, passable in some places in the dry season by motor, but it is not real highway. A slightly less amount remains to be completed from the town of Cartago to the Panama line. The 145 miles of this section will probably be the most difficult stretch in the whole Pan American route, for the road must either ascend to an altitude of over 10,000 feet or else bridge innumerable streams flowing down between the mountain folds.

The ruggedness of Costa Rica is an asset, as well as a liability, for probably no other Central American country, except Guatemala, offers tourists such a variety of scenic attractions. Two active volcanic craters are accessible not far from

the capital, San Jose. The government is completing a concrete highway up to one crater, Irazu. In addition to unusual scenery, Costa Rica offers its capital, San Jose, as one of the most delightful stopping places along the international route in Central America. Besides its ideal climate at slightly less than 4,000 feet elevation, San Jose preserves its early colonial tradition of being the cultural center of Central America. As Guatemala is the most Indian of the republics, so Costa Rica has the purest Spanish blood of the Central American republics.

TYPICAL LANDSCAPE ON A HIGH CENTRAL PLATEAU IN COSTA RICA.

Panama

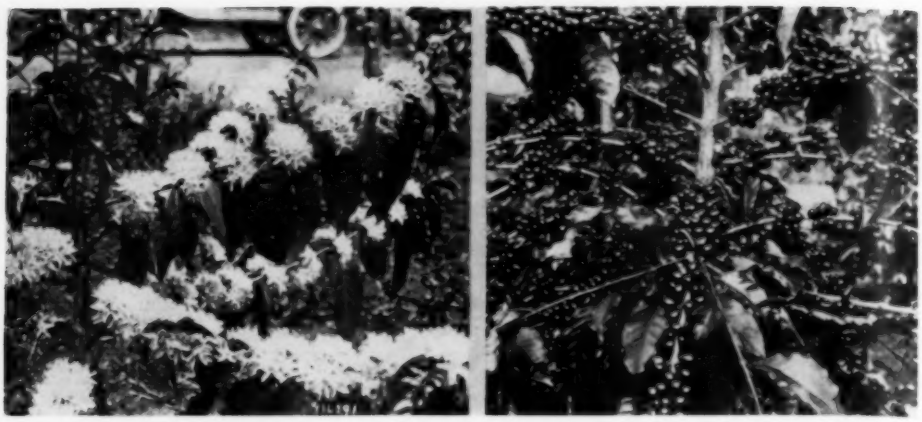
The country of Panama has the longest section of the Pan American Highway route in Central America and also the longest completed section. Of the 367 miles of the international route that passes through this country, over 300 miles are improved, over 200 miles being paved. Less than the 50 miles near the Costa Rican line remains to be graded. The highway, of course, needs much improvement to be made first class. It becomes increasingly better as we go south to Panama City. From the latter capital city modern road building machinery is laying concrete northward. Many old one-way bridges along the route are being replaced by modern two-way structures. The modern suspension bridge across the Chiriqui, below David, is a gift of the United States to this country. Panama has less severe grades along its route of the Pan American system than any other country along the way. Like in all the other countries the highway keeps to the Pacific side, in places passing within sight of the Pacific Ocean. At the same time, it passes through most of the large centers of the country.

With the great number of employees and members of the Army and Navy and of the Canal Zone a little America has been made in the tropics. All the resources of a higher standard of cultural and social living are available here, so that Panama is one of the most attractive places in the tropics for American tourists. Many Americans, pensioned off from service in the Canal Zone, continue to live on estates developed by themselves in the country. As this continues, the country will become increasingly at-

MAKING ROPE FROM A CUBUYA FIBER IN COSTA RICA

WITH A PRIMITIVE TOOL. THE LOOSE BOW MANIPULATED BY THE BOY IMPARTS THE TWISTING MOTION NECESSARY.

A HOSPITAL ON A HILL OVERLOOKING A PARK IN TEGUCIGALPA, HONDURAS.



THE COFFEE TREE IN COSTA RICA.
THE BLOSSOMS AND THE BERRIES OF THE COFFEE TREE.

tractive as a Mecca for tourists from all countries. It is very possible for Panama to become a great Riviera, attracting pleasure seekers from all over the world. Surely it will become a great Mecca for American tourists as soon as the Pan American Highway is opened through Mexico and all Central America. Then, the great middle class American tourist can experience foreign travel and comfortable adventure from his own car over the 3,305 miles from the American border to the Canal. A constant stream of human and freight traffic will, within a few years, be passing overland through strange and interesting lands that con-

DRYING COFFEE IN COSTA RICA.
AFTER COFFEE IS PICKED IT MUST HAVE AN OUTER PULP AND INNER SKIN REMOVED. THIS IS DONE BY MEANS OF A PULP MASHING MACHINE AND WASHING THE BERRIES IN MOVING WATER. THEN THE BERRIES ARE DRIED IN THE SUN ON LARGE FLAT AREAS, GENERALLY OF CONCRETE, AND THIS BECOMES THE COFFEE OF COMMERCE. COSTA RICA PRODUCES SOME OF THE FINEST COFFEE.

nect the two Americas; the dream of great statesmen of both Latin and Saxon America, Bolivar, Clay, Blaine and others, will then be accomplished.

History of the Inter-American Highway Route

At the Fifth International Conference of American States in April, 1923, at Santiago, Chile, delegates from nineteen American republics, with the United States, passed a resolution calling for a conference on highways to study measures for a program of highways within and between the different American countries. Under the leadership of the Pan American Union, a Latin American Highway Commission from all countries toured and inspected the highway systems in many states of the United States in June, 1924. The First Pan American Congress of Highways was called for October 3–13, 1925, at Buenos Aires. This was followed by other tours of Latin American journalists and business men over American highways, mainly under the auspices of organs of the Pan American Union.

At the Sixth International Conference of American States, at Habana, Cuba, in January and February of 1928, a resolution was adopted calling on the Pan American Congress of Highways of Rio de Janeiro, in July, 1928, to consider and adopt agreements on the construction of a road of longitudinal communication across the continent. Meanwhile, the Cole bill, March 26, 1930 (H. J. Res. No. 355, 70th Congress of the United States) was passed authorizing the appropriation of $50,000 to cooperate with the members of the Pan American Union in furthering the building of an Inter-American Highway.

At the Second Pan American Congress of Highways at Rio de Janeiro, from August 16 to 31, 1929, several important conclusions were reached to facilitate the development of inter-American highway systems. Among these conclusions were: that each state should make a study of its own highway system plan and where it could connect up with adjoining states; that a continuous and uninterrupted program should be adhered to; that a uniform code of signs and directions be prepared for adoption.

The first Inter-American Congress of only states of Central and North America was held at Panama, from October 7 to 12, 1929. This group planned an Inter-American Highway Commission to study a possible route and costs. The United States Congress provided for the American participation in this commission of authority in March and June, 1930, and the president of Panama called the whole Inter-American Commission to meet in Panama in March, 1931. Field reconnaissance had already started in September, 1930, in Panama, and in October, 1930, in Honduras under the United States Congressional appropriation act of March 26, 1930. March and April, 1931, saw field reconnaissance begin in Guatemala and Costa Rica, respectively, and in January and December, 1932, in El Salvador and Nicaragua, respectively. By May, 1933, all engineers had completed their field work. The printed report, entitled "Proposed Inter-American Highway," was released in March, 1934.

This Reconnaissance Survey of the Inter-American Highway[1] (Senate Document No. 224, as it is generally referred to) establishes a roughly surveyed line of a highway from the border of the United States to the Panama Canal with the cooperation and approval of the countries through which it passes. Since Mexico has for some time planned, and is putting into execution, her length of this proposed Inter-American Highway, it is not necessary for the report to give much attention to aiding that country.

[1] The Inter-American is that part of the Pan American route down to Panama.

OX-CARTS IN COSTA RICA

ARE A VERY IMPORTANT MEANS OF TRANSPORTATION ON THE DIRT ROADS IN THE COUNTRY.

In the other countries, that is, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama, it does establish a surveyed route. This might be shifted somewhat from time to time as the several countries consider other factors more seriously and as the present construction actually takes shape. Yet, in a general way, it does offer the most reasonable and satisfactory route for an Inter-American Highway route to all concerned.

NOTE: All photographs were taken by the author.

WRINKLES OF ASIA

A STUDY OF MOUNTAIN RANGES

By BAILEY WILLIS

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ARE the wrinkles on our face there because the muscles have pushed or because the flesh has shrunk or the skin has expanded? There is nothing personal in the question, I assure you. I am merely applying the scientific method of multiple hypotheses to the problem of wrinkling, having in mind the wrinkles on the face of Mother Earth and more particularly those on the continent of Asia. They are mountain ranges, you know, and they may perhaps be explained by either one of the three effects I have indicated; that is, because the continent has been pushed or the globe has shrunk or some part of the outer crust has expanded. Geologists familiar with current theories of mountain building will recognize the reference to the speculations regarding Continental Drift and the pushing up of a frontal wave, so to speak, the Andes of South America, for example; and they will recall the old Theory of Contraction of the crust of a cooling globe; but they may not have run across the idea of elongation of crystals and consequent expansion of considerable areas, as suggested by the hypothesis of Metamorphic Orogeny or mountain genesis by metamorphism. It seems to me worthy of consideration, and since it is not so well known, I propose to present it by testing its ability to account for the wrinkles of Asia.

The surface of Asia may be compared to a bas-relief. The background is the vast expanse of plains and plateaus. The raised pattern is a design of mountain ranges. The background itself is neither flat nor level. Some areas lie low, close to sea level, as do the plains of eastern China and of Siberia, including Russia. Others stand high: the plateaus of Tibet, Mongolia, and Peninsular India. The pattern of mountain ranges is raised above the plateaus in a degree comparable with great mountains in Europe and the Americas, 5,000 to 15,000 feet; but where the plateaus themselves are high the ridges and peaks that stand upon them are preeminent in altitude above sea level, the highest mountains in the world. Who does not know Mt. Everest, the supreme peak, whose summit rising to 29,002 feet has thus far defied the most intrepid of mountaineers?

When we look at a work of art, a finished bas-relief, we know that the surface was different before it was sculptured. So it is with Asia. The present landscape is a result of prolonged sculpture by heat and cold (which disintegrate rocks), and by wind and water (which scour off and wash away detritus). The effect of these ceaseless activities in the long, long run is to wear down any height of land to a graded plain, sloping gently to the sea, but before that ultimate result is accomplished the scene passes through a prolonged stage during which valleys widen and heights of harder rock survive as residual ridges and knobs. That is the condition of the plateaus of Asia, in general. It is doubtful if the continent has ever stood at a constant level long enough to have become completely graded. Certainly it is not now so steady. The plateaus whose wide expanses were

FIG. 1. KANCHANJANGA (KINCHINJUNGA) OF THE HIMALAYAS PHOTOGRAPHED FROM DARJEELING, SIXTY MILES AWAY. ALTITUDE 28,140 FEET.

graded when they sloped gently to the sea have recently been elevated high above that position and consequently are being deeply carved by the sawing rivers. Nowhere are there younger, more terrifically abyssal canyons than in Asia. Their precipitous walls, in places ten thousand feet high, demonstrate the recency of the lifting action, which in spite of gravity has raised the plateaus to great altitudes. What is the force that is stronger than gravity?

Thus the background of the bas-relief of Asia puts a question. But what of the pattern of mountain ranges? They too have been elevated, and not simply pushed *up* but also pushed *together*. Each range is a zone of squeezed rock that has been compressed horizontally. Let us consider the mechanical effect for a moment.

The rocks, though some are massive like granite, are in large part bedded; they consist of strata, which were laid down in flat layers and accumulated to form piles of strata many thousands of feet thick. Much of the sand and mud was thus deposited beneath the sea, as is shown by the marine fossils they contain. Now a pile of layers, even of rock layers, can be bent, if sufficient pressure be applied, and beds of sandstone, mudstone and limestone can be bent without cracking, provided they be so loaded that the squeeze holds the rock substance firmly together. That idea, that a sufficient load can control fracture and prevent it, was first clearly stated by Albert Heim, the great Swiss geologist, who grasped it as he examined the arches of strata in the Jura and the Alps. But I think the canny Scot, Sir James Hall, must have realized it when, as long ago as 1797, he laid a heavy door on a thick table cloth and pushed the cloth into folds under the door in an effort to simulate the folds he had observed in strata on the coast. He had the idea of folds all right, but perhaps he did not understand that the effect of the load is to hold the beds together on top of each arch so that they slide past each other on the legs of the structure as they accommodate themselves to the shortening and lengthening of the curves on the inside and outside, respectively. Accommodation by sliding is an essential condition of bending without breaking. Where it can not occur, as in massive rocks like granite, the body yields by shearing into more or less squarish blocks. These details of structure are to be seen in all mountain ranges, and they demonstrate the action of a horizontal force of compression. The mountains of Asia are no exception. They have been intensely squeezed. What can be the origin of a pressure adequate to fold and shear through thousands of feet of rigid rock, shortening the zone by many miles and forcing mountains to stupendous heights? That is another question that is put by the wrinkles of Asia.

There are really three questions: (1) What is the force that lifts plains to the altitudes of plateaus, against gravity; (2) What is the force that acts in a horizontal direction in the earth's skin and produces wrinkles which are mountain ranges; and (3) What is the relation, if any, between the two processes?

These are not new questions. They have been posed repeatedly during the past century and a half and many able thinkers have tried to answer them. Yet there is to-day no general agreement regarding a solution, and skepticism is a common attitude among the best informed. I may, perhaps, state my own position, without offending. It seems to me that the current theories regarding the causes of movements in the earth's crust may be divided into two general classes, namely, those which are purely speculative and those which were framed with less knowledge of geology and physics than we now possess. I can not

accept a gossamer spiderweb of suggestions as the basis of a sound theory, no matter how plausibly the hypothesis may explain certain puzzling phenomena. The Theory of Continental Drift is an example in point. Nor can I think it reasonable to maintain a theory which is based upon concepts of the earth's constitution and history that, though once generally accepted, are now known to have been mistaken. The Contraction Theory is the best known among those of that class.

In theorizing we can not do better, as it seems to me, than to follow the example of T. C. Chamberlin, who together with G. K. Gilbert originated the method of *multiple* hypotheses. He described three methods of mental procedure: the method of the ruling hypothesis, the method of the working theory, and the method of multiple working hypotheses.[1] In discussing their places in the history of scientific investigation he says in part:

> The method of the ruling theory occupied a chief place during the infancy of investigation. It is an expression of a more or less infantile condition of mind. I believe it is an accepted generalization that in the earlier stages of development the feelings and impulses are relatively stronger than in later stages.

Regarding the second method, he says:

> The method of the working hypothesis differs from the ruling theory in that it is used as a means of determining facts rather than as a proposition to be established. It has as its chief function the suggestion and guidance of lines of inquiry; the inquiry being made, not for the sake of the hypothesis, but for the sake of the facts and their elucidation. The hypothesis is a mode rather than an end.

He then points out the danger that a working hypothesis easily becomes the ruling hypothesis and suggests that the defense lies in making a determined effort

> to bring up into view every rational explanation of the phenomenon in hand and to develop every tenable hypothesis relative to its nature, cause or origin, and to give to all of these as impartially as possible a working form and a due place in the investigation.

Chamberlin practiced the method of multiple hypotheses conscientiously throughout his prolonged researches in cosmogony. Toward the close of his career, after thoroughly reviewing and revising the Planetesimal Theory, which in the latest form that he was able to reach is stated in "Two Solar Families," he said to me:

> For twenty-five years I have tested every hypothesis of the genesis of the earth of which I could learn or which I could conceive. One and one only has withstood every critical test. Do you think I am perhaps justified in thinking it probably true?

The method of multiple hypotheses has been for me a difficult, though salutary discipline. It is difficult for me to follow more than one line of thought closely at any one time and in pursuing a selected hypothesis from inference to inference I find myself off on that one track, out of touch with alternatives. Yet one has to choose, and sometimes the choice leads definitely in one direction. For example: In studying any problem relating to movements of the earth's crust it soon becomes necessary to consider the subterrane beneath it. What is its condition, molten or solid? What are the pressures and temperatures at any depth and how do they vary in depth? How does the material react to them if they vary locally?, etc.

In general it appears to be established that the outer crust or skin upon which we live and which is cold and rigid passes into hotter material below and at a depth of some thirty miles, more or less, reaches a temperature close to the melting point. But it is not molten, as I understand the term, for it is elastic (since it transmits elastic, earthquake vibrations). On that evidence the material is elastic to a depth of about 1,800 miles and a shell of that

[1] "The Method of Multiple Hypotheses," *Jour. of Geol.*, Vol. V, 1897.

thickness, which is nearly half the radius of the globe, is distinguished from the central sphere or core, which is relatively inelastic. If we call the eighteen hundred mile thick shell the *mantle*, as some do, we may say that the earth consists of the rigid crust, the elastic mantle and the inelastic core.

Every one will agree that the crust is solid, because we observe that it has the qualities of rigidity, strength and elasticity which characterize that state. But is the mantle solid? If we answer yes, as it seems we should, since elasticity of shape is a typical characteristic of solids, we have to qualify the definition by recognizing that a solid may be plastic and may move like a viscous fluid if it be so confined that it can not break apart. Then, if pushed by a sufficient pressure, it will flow. Lead is made to flow through an aperture in making pipe and so is steel in pressing sheets of it into the shapes of automobile bodies. Rocks of the mantle of the earth flow in a similar manner under like conditions of a load greater than they can bear without lateral support and of a directed force that is adequate to move them. Yet even as the lead and steel are solid, so the mantle may be regarded as solid, though plastic.

A plastic solid seems peculiar because we are not familiar with the condition of excessive confining pressure. There is another characteristic of solids with which we are even less commonly acquainted, and that is *fatigue*. We all know how it feels when a muscle gets tired, when its nervous energy is exhausted and it relaxes. Something similar occurs in metals and other substances. For instance, steel tapes, 500 feet long, were once hung in the Washington Monument and stretched by a slight weight. If the weight was removed they shortened elastically to their original length; that is at first; but after some months they could not recover; the steel had become fatigued. A more familiar illustration of the same property may be noted when a stick of sealing wax is held out horizontally while fixed at one end. It will support its own weight rigidly for a time, but will eventually sag down. The atomic forces which had held the steel or the wax to a rigid form eventually yield to the persistent stress, slight though it be, and the solid suffers a strain from which it can no longer recover by elastic rebound.

Fatigue is thus seen to be a question of *time*. We may say that fatigue is a condition to which solids and liquids both are liable, but with this distinction: in a perfect liquid fatigue is instantaneous; in a perfect solid it ensues only after the lapse of infinity. You ask: Are there such substances? I think we may say yes. There are many, well-known liquids that yield at once, and a granite which has maintained crystalline texture for two billion years might be cited as an example of the perfect solid. Perfection, however, is rare and impermanent in the material world, and many substances may be regarded as solid or liquid, according to the manner in which they resist for a shorter or longer time, under different kinds of stress.

Returning from this excursion into generalities to the question, Is the mantle solid?, we might compare the rocks of which it consists with granite and other assemblies of crystalline minerals and take the affirmative on the ground that its substance is elastic and does not show evidence of fatigue after an indefinite lapse of time. It seems as though that position were sound. Yet it is not the last word, for there are materials, such as glass, which are elastic and will yield to slight stresses in due course of time; they may, therefore, be classed as liquids. To the extent that glassy rock may constitute a part or the whole of the mantle, it might be considered a kind of liquid

with regard to its resistance to persistent pressure, however slight, although it reacts like a solid, elastically to sharp shocks.

It has been necessary to clear up this question of the solid or liquid state of the mantle, because no one knows surely how much of it may be crystalline or glassy and the uncertainty fixes the parting of the ways for two different hypotheses. The one postulates a predominately crystalline mantle, 1,800 miles thick, the other assumes the presence of a glassy shell of notable thickness in the crystalline mantle. The former is obliged to consider the mantle very strong; the latter can appeal to relatively slight forces to cause great movements in the course of geologic ages.

Pursuing the method of multiple hypotheses we can not arbitrarily set either of these alternatives aside as negligible unless we can disprove it, no matter how incredulous we may be regarding its value. Definite proof of strength or weakness in the mantle is not now possible; therefore both hypotheses must remain on the list of possibilities. And yet it is not practicable to carry both of them simultaneously in mind through the maze of natural phenomena we must explore in seeking the solution of such a problem as that of mountain growth. We stand at the forks of the path, and we must choose either the right hand or the left for immediate exploration; but we may not forget to return sooner or later to see where the other leads, unless others have adequately explored it.

We will for the present take the right-hand fork, which leads into the strong, crystalline mantle. The alternative of a glassy shell is meantime being examined by Professor R. A. Daly and his students of Harvard.

The first question relates to energy. If the mantle is solid we must show that great forces can be brought to bear to overcome the resistances. Gravity, to which geologists are accustomed to appeal for help, is quite incompetent. It may work if adequately disturbed, but it can not start from a balanced condition. Heat is a powerful stimulant, but it also is balanced if it is symmetrically distributed. One of the common notions about the globe is that it is cold at the surface and very hot inside and grows hotter and hotter as the core is approached. The idea is that at any given depth we would encounter the same temperature, no matter from what point on the surface we started. The same picture is presented by the so-called shells of the globe. Geologists discuss an outer granite shell, beneath which there may occur in succession a basalt shell, a peridotite shell and possibly others of still denser, heavier rock. Various physical characters, such as density, elasticity, etc., are thought to be arranged in definite shells, giving the globe a stratified structure. The idea springs from the assumption of a once completely molten globe, in which the materials were sorted by gravity, so that the heavier substances sank toward the bottom, while lighter ones rose to higher levels. It implies that the stratification was not materially disturbed by any boiling of the huge mass and that there has been little or no change in the internal structure during subsequent geologic ages. No one can say that it is not a true picture; but there is an alternative: The materials of the globe may be distributed more or less heterogeneously, they may be hotter or cooler at the same depth along different radii, they may be solid in general and yet melted in places in the mantle, and the related physical characteristics may be irregularly variable. Here then are again two paths to pursue, the homogeneous or the heterogeneous. Since we can not offhand prove either of them wrong we must retain both of them in mind, while we

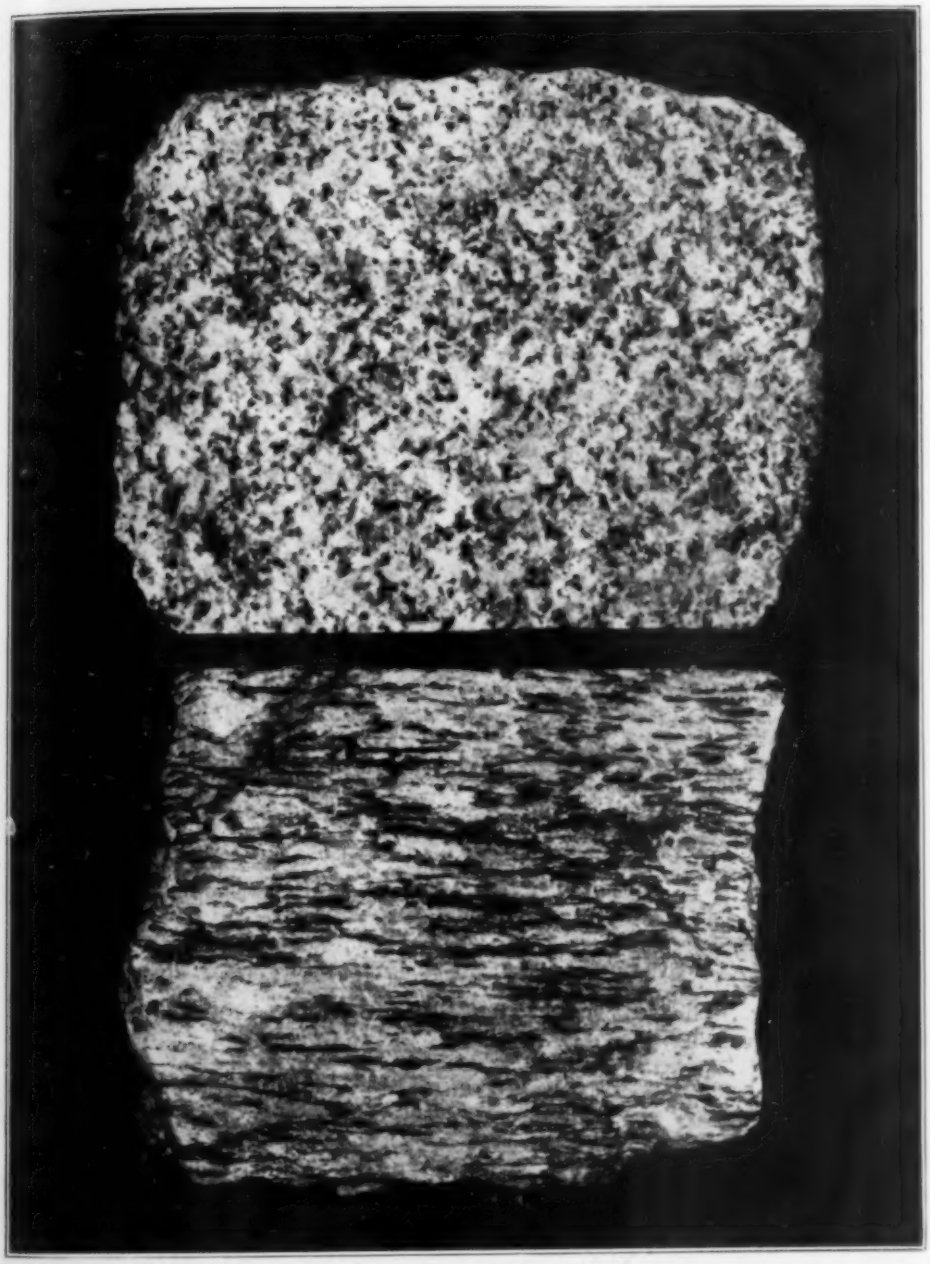
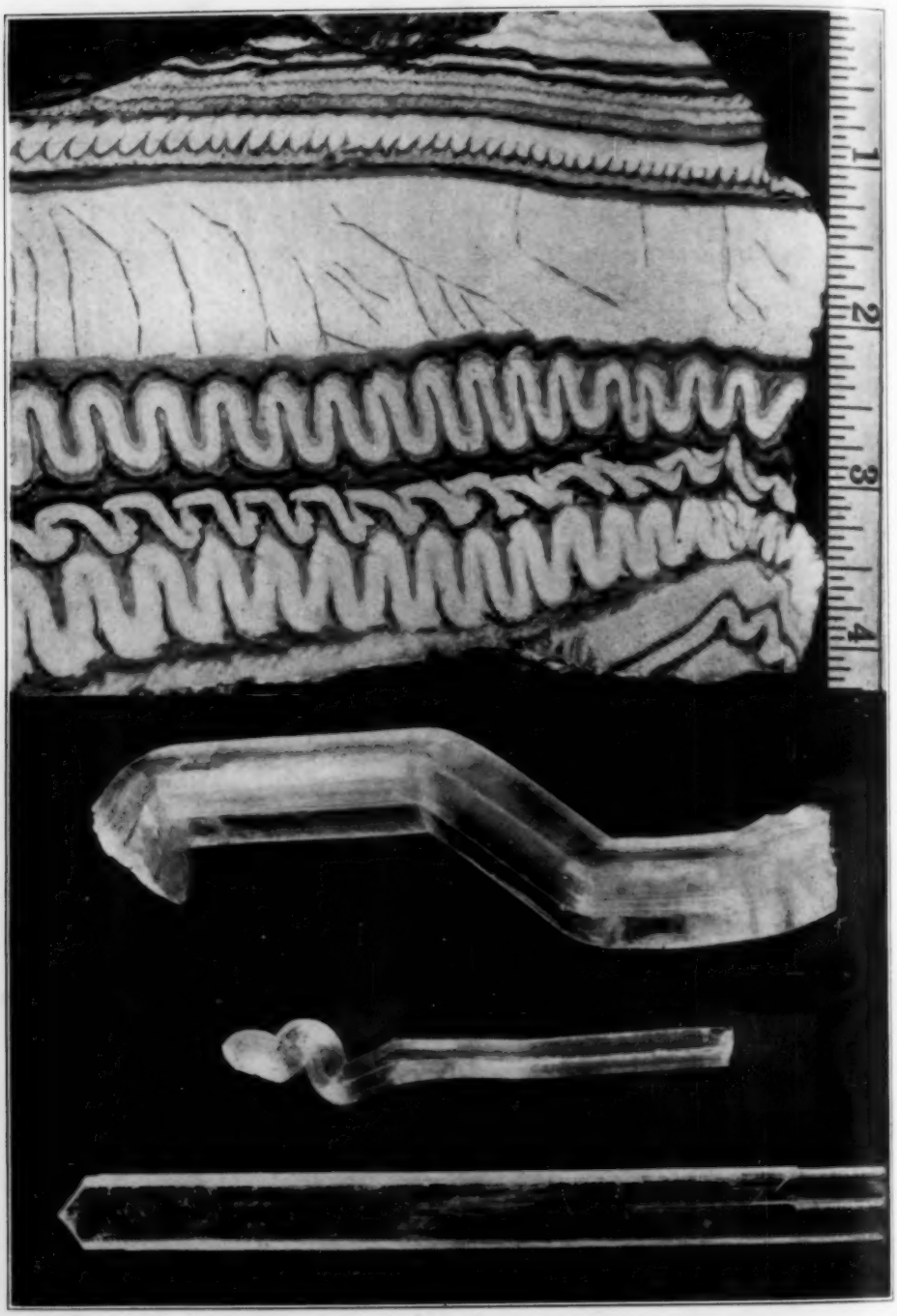


FIG. 2. CRYSTALLINE STRUCTURES, GRANULAR AND LAMINATED.

THE GRANULAR TYPE FORMS WHEN THE ROCK CRYSTALLIZES FROM A MOLTEN CONDITION, UNDER HYDROSTATIC PRESSURES. THE LAMINATED TYPE DEVELOPS WHEN THE GRANULAR ROCK RECRYSTALLIZES WITHOUT HAVING BEEN REMELTED, AS A SOLID, UNDER UNEQUAL PRESSURES. IT IS THEN SAID TO BE METAMORPHOSED.


1
2
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4

FIG. 3. THE POWER OF CRYSTALS IN PROCESS OF FORMATION.

Top. THE WHITE MINERAL (GYPSUM) REQUIRED MORE ROOM THAN ITS PARENT (ANHYDRITE) AND TOOK IT BY FOLDING UP AND LIFTING THE LOAD. *Middle.* THE TWO CRYSTALS OF GYPSUM DEVELOPED IN CONFINEMENT AND WERE FORCED TO BEND AS THEY GREW AGAINST AN IMMOVABLE BODY. *Bottom.* A STRAIGHT CRYSTAL OF GYPSUM, WHICH GREW FREELY.

EFFECT OF INCREASE IN VOLUME IN SOLID ROCK

THE UPPER SPECIMEN ILLUSTRATED IN FIG. 3 CONSISTS OF GYPSUM, THE HYDRATED CALCIUM SULPHATE, $CaSO_4 + 2H_2O$. IT WAS ORIGINALLY THE MINERAL ANHYDRITE, CALCIUM SULPHATE, $CaSO_4$, WITHOUT WATER. IN COMBINING WITH WATER EACH MOLECULE INCREASED IN SIZE IN APPROXIMATELY THE PROPORTION OF 3 TO 4. THE SWELLING CRYSTALS DEMANDED SPACE AND TOOK IT BY LIFTING THE LOAD. THE PROCESS APPEARS TO HAVE BEEN SOMEWHAT AS FOLLOWS.

ORIGINALLY THE ANHYDRITE WAS PRECIPITATED FROM SOLUTION IN A BODY OF WATER AND ACCUMULATED AS SEDIMENT IN FLAT LAYERS ON THE BOTTOM. THE PRECIPITATION WAS INTERRUPTED FROM TIME TO TIME AND LAMINAE OF DARK COLORED CLAY WERE DEPOSITED, SEPARATING THE WHITE LAYERS OF ANHYDRITE. IN THE SUBSEQUENT CHANGES THE CLAY REMAINED PASSIVE, BUT AFFORDED GLIDING SURFACES FOR THE ANHYDRITE.

AS IT COMBINED WITH WATER EACH CRYSTAL OF ANHYDRITE CHANGED FROM SQUARISH TO FLAT ELONGATED FORMS OF GYPSUM AND FORCIBLY TOOK ADDITIONAL SPACE, PUSHING OTHER CRYSTALS AWAY. IF, AS MAY BE ASSUMED, THE ACTION WAS MORE INTENSE OR BEGAN EARLIER AROUND CERTAIN FOCI, THE MUTUAL PRESSURES OF ADJACENT CRYSTALS WOULD ADD UP RADIALLY OUTWARD FROM ANY SUCH POINT OR LINE AND THE EXPANSION WOULD BE LIKE THAT OF A GROWING SPROUT. WHEN THE SUM OF PRESSURES IN A LINE OF CRYSTALS INCREASED TILL IT COULD LIFT THE LOAD AN ARCH BEGAN TO FORM AND IT ROSE PROGRESSIVELY, THOUGH PROBABLY A NUMBER WERE GROWING NEARLY SIMULTANEOUSLY SINCE THE SWELLING WAS GENERAL. THE LENGTH OF ANY FOLD (TWICE THE HEIGHT OF THE CLOSED ARCH) WAS DETERMINED BY THE STRENGTH OF THE LAYER AS AN ARCH IN RELATION TO THE LOAD AND AS MODIFIED BY FRICTION. THE THICKER THE LAYER OR THE LESS THE LOAD, THE LARGER THE ARCH OR FOLD.

THE LAYER WHICH COULD NOT FOLD EASILY BECAUSE IT WAS TOO THICK, YIELDED BY SHEARING BEFORE IT COULD ARCH UP, AND THE FRACTURES ASSUMED VARIOUS ATTITUDES ACCORDING TO THE INTERNAL STRESSES. BUT THEY INDICATE A PUSH FROM RIGHT TO LEFT AS DO THE OVERTHRUSTS IN THE LAYER BELOW.

THE FORCES THAT DID THIS WORK WERE THE ATOMIC FORCES, WITH WHICH 2 MOLECULES OF WATER COMBINED WITH EACH MOLECULE OF THE SULPHATE. THEY PRODUCED THE COMBINATION WITH INCREASE OF VOLUME IN SPITE OF THE CONFINEMENT IN THE SOLID ROCK AND AGAINST THE FORCE OF GRAVITY.

follow one or the other to its logical conclusions by testing it against some array of facts. In this case I propose to take the path of investigation that leads into the solid, *heterogeneous* mantle.

We start from the observation that the crust is very heterogeneous; it is made up of many kinds of rocks, which are very irregularly distributed. Furthermore, rocks of one and the same composition and character are of very different ages; there are granites that are one or even two billion years old and there are granites which are surprisingly young; the same is true of basalts and other kinds of rock. There never has been a time when the crust was not heterogeneous or was not made up of older and younger erupted masses. What we now assume is that the mantle resembles the crust in the irregular distribution of materials and temperatures, and always has done so.

All right. We now have under consideration a heterogeneous sphere, consisting of a very thick, solid mantle and thin outer crust, surrounding an apparently molten core. The whole is charged with energy in the forms of gravity and heat. Gravity is a permanent, conservative force. Heat is a stimulant to action, but it is used up in doing work and it also escapes into space. Since the earth is so very old and so much work has been done, all the heat energy from any original source such as a molten globe must long since have been exhausted. Yet the earth is exceedingly active. How has the heat energy been kept up?

It may be recalled that astronomers and physicists at one time set a rather narrow limit on the possible life of the sun because it was radiating heat at a rate that could not be maintained for many million years, if it were due to the condensation of the sun's mass by its own gravitative attraction alone. Madame Curie solved the riddle when she discovered that an atom of uranium could and did change to lead and gave off heat in so doing. Atomic transformation is now recognized as the potent source of the heat of the sun and stars.[2] It also occurs in rocks of the crust of the earth in the so-called radioactive minerals. The thought lies at hand that similar reactions, occurring within the mantle, would generate heat and so keep the earth alive. Investigations of this potent source have shown that it would long since have caused the melting of the earth if the proportion of radioactive minerals were the same throughout the mass of the globe as it is in rocks at the surface. Since the earth is not melted some limitation becomes necessary, and it has been attempted by several geologists by assuming that the active minerals may occur only in some thin shell of the supposedly stratified mantle. That is one idea. Another is that the active minerals may be irregularly distributed, as ores of gold are, for instance.

Let us suppose that anywhere in the mantle there is a body of rock which contains more radioactive minerals than the adjacent masses and that there are also other bodies that contain little or none. The radioactive minerals slowly change and in changing give off heat, which being buried in the globe can not escape by radiation or conduction. It must accumulate and melt the rock, the richer bodies melting first. Each one would then constitute a growing bubble of molten rock in the not yet melted surrounding rock. It is true of such a bubble, as it is of a bubble of gas in a liquid, that it must rise toward the surface whenever it gets big enough; and it is also true that it must spread out as it rises from depths where the pressure is greater into those where it is less.

[2] Russell, H. N., *Proc. Am. Phil. Soc.*, Vol. 81, 1939.

The general form of the bubble at higher levels will therefore be that of a flattened rounded disc. That is, so long as it is confined in the solid, but plastic mantle; when it reaches the rigid outer crust, it will tend to spread even more widely underneath it and also to penetrate any weaknesses, such as shearing planes, in its effort to rise still further. It then becomes an intrusive rock, forming narrow bodies, which may, however, be large enough to constitute such a mountain range as the Sierra Nevada in California.

Continuing this thought, we may suppose that such a body rose and having spread out cooled in the upper part of the mantle or lower part of the crust. It is then a compact, solid mass and as such offers more resistance to the rise of any later melt, which may come up from its heated roots, than that which is presented by the disturbed and altered rock around it. The later melt is therefore apt to appear as intrusive bodies or as volcanoes in the circumference of an older one. Such an arrangement is a common one, as we see in the arcs of volcanoes in the Pacific, for example, and also in the distribution of mineral deposits.

Have you clearly in mind the picture of the flattened bubble of molten rock or magma underneath the outer crust? The melt is surcharged with energy, it being hot and chemically active. The rock of the covering crust is crystalline, that is, it consists of crystalline minerals which are composed of molecules, in each of which the atomic forces are balanced. But they attained that balanced condition as the rock of the cover cooled from some previous heated state and now, being reheated, they will be disturbed. The crystals will reform in response to the chemical excitement and the external pressures around them, or, as the phrase goes, the rock will be metamorphosed. (Fig. 2.) In the process of change the molecular forces of the original crystals will become unbalanced and will enter forcibly into the reorganization of the minerals, but they will be influenced by any other stresses, such as surrounding pressures, because they must obey the law that requires the work shall be done with the least expenditure of energy, the law of least resistance. They will forcibly elongate in the direction toward the least opposing pressure, whatever that direction may be. What will it be under the conditions in the upper part of the mantle above the contact of the magma and its cover?

At the depths at which the recrystallization is supposed to occur the rock is under a weight greater than it can carry unless it be supported by adjacent masses. Equilibrium depends, therefore, upon the balance between the weight which is carried and the supporting resistances. The resistances are two, namely, the strength of the rock (whatever value it may have) and the horizontal pressures of adjoining masses. The latter will be less than the weight, for the strength is something. (Weight minus strength equals horizontal pressures; hence horizontal pressures less than weight.) If we now introduce the molecular forces of crystals in process of change we disturb the balance and the crystals in reforming must elongate in the direction of least resistance, that is, horizontally. This is the reasoning which it at the foundation of the hypothesis to be discussed, the hypothesis of *Metamorphic Orogeny*. Orogeny or mountain-genesis is by that hypothesis attributed to the force of growing crystals, which have elongated in the lower portion of the cover of a bubble of magma and have caused the cover to expand in such a manner and with such force that the margins are pushed up as mountain ranges: first the hot bubble, then the

gradual development of expansive force in the cover till the crust yields.

That is a stupendous job! Is it possible that it can be done by hard, inert substances like crystals? That is just the point: they are hard and inert because they are so firmly held in balance by very great forces. When those are released they reconstitute the crystal with proportionately intense action. It has been determined by experiment that in crystal growth and change the *molecular forces come into play and cause the growing or recrystallizing structure to exert a force that is equal to the crushing strength of the crystal.*

To illustrate crystalline change and the forces that may be exerted, even when the alteration occurs in cold rock, with no impulse except that of chemical attraction, attention may be directed to the example shown in Fig. 3. The white layers in that rock are gypsum, the common rock of which plaster of Paris is made. They were originally, when deposited under water, a slightly different mineral, called anhydrite, which consolidated to rock. On being brought in contact with molecules of moisture each molecule of anhydrite took on one and thereby increased in volume; every 3 cubic inches became 4 cubic inches. There had to be room and it was made by lifting the load, whatever it was. But the lifting was accomplished by the layers, which were originally flat. They elongated horizontally, exerting molecular force in so doing. The individual crystals got behind each other and pushed the layer up into an arch, sliding it along on the interstratified layer of black clay beneath it. As any one arch rose another began behind it and so a short section was folded up by the expansion of a very long stretch that remained flat. The force that was exerted was equal to the shearing strength of the rock, as is shown by the fact that the layer which was too thick to fold was sheared along the dark, fracture lines.

The writer had a personal experience which is to the point. It occurred when the Hetch Hetchy tunnel was being driven through the Coast Range near San Francisco, California. Several miles of it penetrated a very unpleasant black schist, made up of very thinly laminated mica. The mica-scales were not more than a few molecules, a few hundred thousandths of an inch thick, and between each pair of them were invisible cleavages into which molecules of water were drawn from the moisture of the air in the tunnel. The molecular attraction was not very strong in any individual entry, but the combined effect of millions was irresistible. It crushed the strongest timbers and squeezed out solid blocks of sandstone, where they were imbedded in the mica rock. I saw it done. Having climbed to a platform at the face of the tunnel and finding a projecting rock, I struck it with my hammer. It responded at once, moving menacingly toward me, like the front of an automobile about to run over me. That rock was alive and seemed possessed of a malicious spirit.

These instances which have been cited to illustrate the force of crystals in growth or metamorphism present only minor effects, such as are produced without stimulation by heat. The reactions are far more intense when the molecules are strongly agitated, as at high temperatures. Very pronounced changes are seen in metamorphic rocks, where great alterations have been brought about at temperatures that approached the melting point. High pressures also increase the action, and this is especially the case when there is sliding of one mineral over another and the mass is sheared into thin plates. The molecular forces are then intensified by the shearing stress and the temperature is raised by the friction. Extreme elongations amounting to sev-

eral times the original dimension in a given direction may result as the rock becomes fissile or even fibrous.

Let us examine the process of change more closely. Any response of the molecular forces to slowly rising temperature must itself be very gradual. Any individual crystal should experience a slowly growing tendency to change its form. When it eventually does so it obeys the law of its own being and adjusts any dimension according to the particular arrangement of atoms that best suits the environment along any given axis. Any crystal changes without regard to its neighbors, in the beginning. The effect within any area of a square foot or square mile is that of a mob. But groups will by the law of chance develop mechanical resultants and so dominate contiguous individuals as to work them into the common trend. In that trend the elongations of the individual crystals add up and the effect at the outer end of the line is a push with their combined forces and a displacement equal to the sum of their elongations.

We may get some idea of the possible proportions of the change by considering the alteration of a granular igneous rock like granite or of a granular sedimentary rock like sandy mudstone to a laminated metamorphic rock with development of the common mineral, mica. Measurements of mica crystals show that if the mineral substance originally had the form of a cube the length of the oblong, flattened mica crystal would be twice the side of the cube. That is to say, the elongation in one direction would amount to 100 per cent., with corresponding thinning in other directions, provided there is no change of volume. In those cases where the greenish, fibrous minerals grow the change of proportions is even more. Indeed we might easily be misled into describing the elongations as amounting to exaggerated proportions if we did not distinguish between the effect of recrystallization, which exerts a molecular stress, and the effect of plastic flow, which is simply a squeezing out. But we do not need to assume extreme conditions. The horizontal dimensions of the larger molten bodies and the diameters of their covers are many miles in extent.

Consider, for example, the plateaus of Asia, the nuclei of the continent. We have noted in a previous article[3] that they have repeatedly been intruded by molten granite, which has risen into and around the older eruptions in each successive activity. The diameters of the areas thus intruded are many tens of miles, even two or three hundred. The proportionate expansion need not be great to produce an outward push and displacement amounting to miles in their margins.

We may not let such an estimate pass, however, without recalling the dictum of Professor Andrew C. Lawson, of the University of California, who has shown that in case of movement of one rockmass over another the dimensions of the moving mass are narrowly limited by the weakness of the rock.[4] The friction sets a limit for the length of a slab which may be pushed over another without being sheared. How can a layer tens of miles in radius be pushed away from a central area? Yet that seems to be the fact, since mountain zones are narrowed in that degree. Could Professor Lawson be mistaken? In this case it would appear that he is not, for the conditions which he assumed would not exist. At the contact of the cover with the underlying magma there is a transition layer in which plastic solids, molten liquids and hot gases are mingled and agitated by their mutual reactions. Do you get the

[3] "The Growth of Asia," SCIENTIFIC MONTHLY, June, 1939.

[4] "Isostatic Compensation Considered as a Cause of Thrusting," *Bull. Geol. Soc. Amer.*, Vol. 33, 1922.

picture? The slab or disc which constitutes the expanding cover rests upon this agitated fluid and gaseous contact zone. There is no friction, only a moderate resistance due to viscosity, and that is variable from place to place. Only when the margin of the magma is reached and the outward thrust begins to displace the solid framework would the friction of solid-on-solid come into play. Even then it would be lessened in any case where hot gases or melts followed intrusively along developing shears. The outer slab that might be sheared off in this manner is such as we see as an overthrust sheet, and its dimensions are commonly of the same order of magnitude as those calculated by Professor Lawson, with lengths of fifteen to twenty miles.

Reviewing the substance of the preceding pages, it appears that the hypothesis of Metamorphic Orogeny is equipped with power, may work with a terrestrial mechanism, and would by known processes of metamorphism achieve the upthrust of mountain arcs. It may be explained that it is the survivor of a number of hypotheses to account for the folding of zones of the crust, which have been submitted to the tests of advancing knowledge, so far as the writer was able, during the past fifty odd years. The list comprises all that have come in to his research net, including some that are still current with one school or another. But all the others have failed, in his estimation, because they were either impotent or inadequate or mechanically defective or based upon assumptions that were in course of time disproved. It does not follow, even in the writer's thought, that Metamorphic Orogeny is sound, but it is entitled to further consideration and may be tested against the facts presented by the development of various mountain chains, so far as they are known. It is my purpose to do that in a number of cases, but in order that the hypothesis may not lead me to believe that it is the ultimate answer (where we have so much to learn), I have laid down certain requirements which it or any competitor must satisfy to be admitted to examination. The habit of examining students for graduation leads one to regard any such hypothesis as a candidate for the degree of W. H., Working Hypothesis, and I would guard that degree as an honorable distinction.

Any hypothesis must be dynamically competent; that is, it must assume a source of energy, which will deliver power at the right time, in adequate amount, and in the right manner to do the work. As a second requirement the hypothesis must operate according to mechanical principles, with rocks of the crust, on the scale of mountain building. Again, it must be capable of repeated action in the same region, after long intervals of inaction. It must produce the peculiar pattern of curving mountain ranges, with abrupt terminations, and with nodes where two or more trends meet. And the action must cooperate with or be related to other processes of terrestrial activity proceeding from a common cause in the same region, at the same time or in sequence.

Most of these requirements seem sufficiently obvious, though often disregarded, but the concept of pattern may be more fully considered, because it is significant and the discussion may serve to point out certain misinterpretations.

Eduard Suess, the great Austrian geologist who compiled the monumental work, "The Face of the Globe," was the first to note and interpret the curved axes of mountain ranges. His primary example was the Alps, which arch around the northern margin of the elongated basin of the Po. Suess took the arc to be an effect of bending and reasoned that the force which had caused it had acted to push the Alps northward. Generaliz-

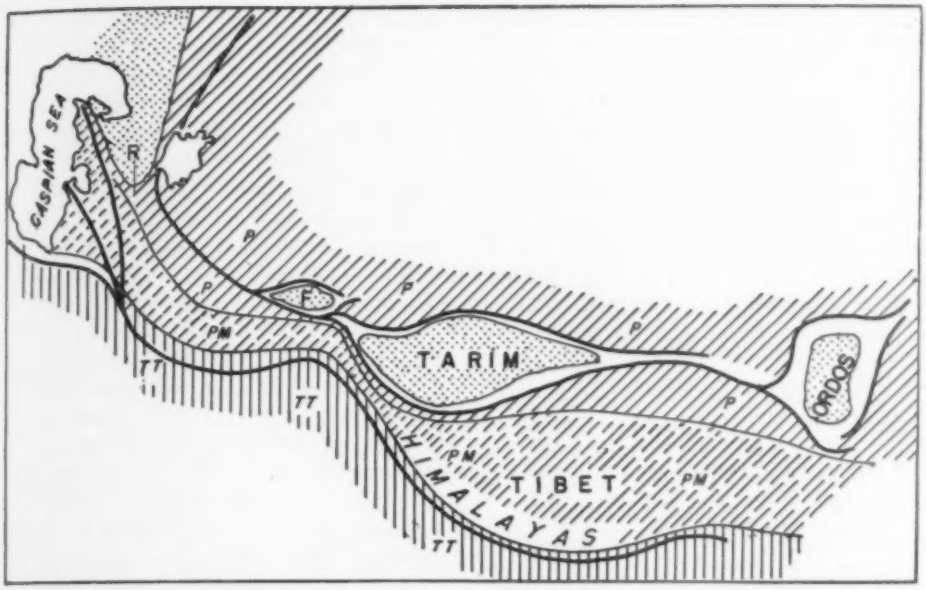

FIG. 4. STRUCTURE OF CENTRAL ASIA. DIAGRAMMATIC OUTLINE AFTER LEUCHS, GEOLOGIE VON ASIEN, 1937. OLD LANDS (PRE-CAMBRIAN) INDICATED BY DOTS. MOUNTAIN TRENDS SHOWN BY HEAVY LINES. AREA PPP IS THAT WHICH IS CHARACTERIZED BY LATE PALEOZOIC FOLDING. AREA PM IS THAT IN WHICH BOTH PALEOZOIC AND MESOŽOIC FOLDINGS ARE RECOGNIZED. AREA TT IS THE ZONE OF TERTIARY OVERTHRUSTS, PUSHING OUTWARDS OVER THE GANGES DEPRESSION. THE ENTIRE REGION OF THE MAP IS DOMINATED BY THE YOUNG MOUNTAIN RANGES THAT HAVE BEEN PUSHED UP DURING PLIOCENE AND PLEISTOCENE TIMES AND HAVE ALSO BEEN LIFTED BODILY WITH THE PLATEAUS. F—FERGHANA NUCLEUS; R—RUSSIAN NUCLEUS.

ing on the concept, he applied it to all mountain chains and gave it definition by naming the front, the flanks, and rear, according to their relative positions, as of an advancing army.

The generalization has been fully justified, and it may be amplified by pointing out that the arcs of mountain chains tend to occur as the raised margins of basins. Look at the great plain of Hungary lying within the Carpathian curve and separated from the Adriatic depression by highlands of Bosnia and Dalmatia. Consider the Adriatic itself, bounded by the highlands on the northeast, the Alps on the north and the Apennines on the southwest. With attention turned to the hollows or concavities of the earth's surface we may note the fact that Suess's interpretation means that the mountain-building force has raised the rims by pushing outward, away from the interior.

The ideal pattern would consist of round basins, but the effect is evidently not so regular. Some depressions are oval, others are decidedly long. Where they are closely contiguous the common margin may run straight, as if mutual pressures had been opposed. And where two or more meet at their ends there is a mountain knot.

Suess applied the interpretation of mountain arcs, considered as evidences of an outward push, to Asia and logically reasoned that the great sweep of the Himalayas with its convexity toward the south implied a southward movement of the whole continent or of that broad mass of the continent north of the arc.

The idea suggested a drifting movement of the whole, to which it may be objected that there is no known force to cause such a displacement and there is behind the continent, north of it, no such hollow as its southward drift must have left. The Siberian nucleus has not been disturbed during the several hundred million years which cover the time of the evident mountain-making episodes and seems to have been a fixed, possibly resistant mass. Reasoning thus, Willis in 1907[5] argued that the arcs might have been raised by a push from the oceanic regions toward Siberia. He thought the source of pressure should be sought in the Pacific and Indian oceans. He was, I now think, influenced by his early observations in the Appalachians, where the push was from the direction of the Atlantic. He thought that ocean basins were the dynamic areas, that the continents were passive and that the latter had been squeezed, either by expansion of the former or by wedging. It was not until many years later that he realized the incompetence of the crust to transmit mountain-building pressures to any considerable distance from their source and on that ground relegated the idea of *exclusively* oceanic expansion to the scrapheap. The study of continental masses and their histories convinced him that they also had been areas of dynamic activity and that in that respect there is no characteristic distinction to be made between the crustal areas covered by the oceans and those which are lands. He was thus led to consider the alternative hypothesis of expansion of smaller areas, which is the basis of the present discussion.

The wrinkles of Asia and the nuclei which they outline offer a number of opportunities for testing any hypothesis of local expansion, whatever be the supposed cause. There are the ancient continental islands: the Angara nucleus, the Gobi desert area, Tibet, the Tarim plateau, the Peninsula of India and others which are less conspicuous. Each of these nuclei had a long history of intrusion and mountain growth before the mountain trends we can now recognize were developed. That ancient record has not been deciphered. Among the more recent activities the periods of granitic intrusion and orogeny which occurred at the close of the Paleozoic era and again during the later Mesozoic and Tertiary, respectively some 200,000,000 and 60,000,000 years ago have left elements of the pattern which invite consideration. The earlier of these two may presumably be studied in the Gobi region and the mountain arcs which surround it on the south and southeast, the enormous mass of the Great Mongolian granite, which rose toward the surface in that area during some period of the Paleozoic being the exciting fact; but the case lacks definition because the date of the intrusion is not yet well established and its relation to any epoch of folding can not be determined. The Mesozoic record is more evidently related to the outstanding mountain ranges. Even there, however, where we see the youngest visible granites at the surface, we have to remember that they are older than the youthful mountains and that any magma to which we may attribute metamorphism or other effect must be hidden beneath the crust, under the plateaus.

It happens that the most conspicuous of all mountain chains, the Himalayas, is that of which we have more precise knowledge and which best lends itself to our purpose of testing Metamorphic Orogeny. The arc sweeps majestically around the southern margin of the Tibetan nucleus. It is marked by a central zone of granite of late Mesozoic and Tertiary age, part of the widely distrib-

[5] "Research in China," Vol. II, pages 118–126.

uted intrusions of that time, which built up southeastern Asia as we now know it. The mountain mass is intensely sheared and folded, squeezed into a relatively narrow belt. The apparent movement has been away from Tibet and toward the Ganges depression, as is seen at the southern base of the range, where the foothills are thrust out upon the valley plain. But we will do well to pause and consider our postulates, before we are carried too far by favorable appearances.

Our basic assumption is that there is a molten body beneath the plateau of Tibet. What evidence is there to justify that? There is no conclusive evidence. In the absence of volcanoes or other surface indications of subterranean heat the assumption is an inference, which, however, may put in claim for acceptance as such on the following grounds. It is established by the occurrence of the Tertiary granite that there was during a geologically recent time a highly heated condition in the marginal zone of Tibet, at a depth from which that body was extruded. It is improbable that the crucible could have cooled to solidification, if situated at even a moderate depth below the crust; and even though it lost a large amount of energy in consequence of the extrusions, it remained liable to reheating by any remainder of radioactive minerals, *i.e.*, heat generators.

A second reason for thinking that there may be a molten body beneath the Tibetan plateau springs from the elevated position of its eroded surface. The type of flat plain, dotted with residual hills, to which it belongs, can be sculptured only near sea level. It has been raised some 15,000 feet. There are three ways in which such an uplift may be produced; a section of the crust may be squeezed up, as mountain ranges are; or it may be arched up by the intrusion of lava between two layers, as in the classic instance of the Henry Mountains in Utah; or it may be lifted in consequence of and by an increase in *volume* of underlying rock. An example of the first kind, a mountain range, is long and narrow and presents a characteristically crushed and folded structure. Belts of that nature occur in the Tibetan plateau, but they represent older mountains and can not be the cause of the younger uplift. The possibility that a layer of rock, 15,000 feet thick, may have been inserted beneath the plateau is ruled out because any such mass would have increased the attraction of gravity over the average normal value and observations fail to indicate that excess. There remains the inference that the volume of an underlying mass has been increased, as by a swelling action. The alteration of anhydrite to gypsum, which we have noted, suggests one process, but it is not probable that any transformation of minerals could occur throughout a layer of sufficient thickness and extent to produce the elevation. Another process, and the only one possible so far as we know, is melting. It is an appropriate action, since it would affect every square mile similarly and would produce a more or less uniform uplift. The increase in volume, concentrated in vertical displacement, would be about 5 per cent. of thickness of the solid rock before melting; that is to say, a layer 60 miles thick should have melted to produce an uplift amounting to 3 miles. Given a highly heated body, containing sparsely disseminated heaters and situated in the mantle, below the crust, melting appears to be reasonably probable.

A sidelight may be thrown upon this inference by reference to the fact that the Himalaya mountains are lighter, considered as a weight on or in the earth's crust, than they would be expected to be. This fact was discovered by the surveyors of India as far back as 1855, and it led to the suggestion that the mountains had

FIG. 5. MOUNTAIN RANGES OF ASIA. THE HEAVY BLACK LINES REPRESENT THE AXES OF MOUNTAIN CHAINS, WHICH SURROUND OR SEPARATE NUCLEI OF THE CONTINENT. THE MOUNTAINS ARE MADE UP LARGELY OF SEDIMENTARY ROCKS, THAT WERE DEPOSITED BENEATH MARINE WATERS. THE NUCLEI CONSIST CHIEFLY OF GRANITE INTRUSIONS AND METAMORPHOSED ROCKS; THEY HAVE BEEN DEEPLY ERODED AND WERE THEREFORE LAND AREAS. THUS THE MOUNTAIN RANGES AND NUCLEI PRESENT A PICTURE OF AN ARCHIPELAGO COMPOSED OF CONTINENTAL ISLANDS AND OCEANIC STRAITS. THERE ARE GREAT DIFFERENCES OF AGE AMONG THE ROCKS. YOUNGER SEDIMENTS AND MORE RECENT INTRUSIONS OF GRANITE ARE FOUND IN THE HIMALAYAS, THE MALAY PENINSULA AND SOUTHEASTERN AND EASTERN CHINA. OLDER SEDIMENTS CONSTITUTE THE CENTRAL AND NORTHERN MOUNTAIN RANGES. EACH OF THE MARINE STRAITS WAS CLOSED IN TURN WHEN THE SEDIMENTS DEPOSITED IN IT WERE FOLDED UP AND RAISED AS PART OF THE CONTINENT. THUS ASIA HAS GROWN FROM NORTH TO SOUTH AND SOUTHEAST BY THE WELDING TOGETHER OF THE NUCLEI. THE PENINSULA OF INDIA IS A VERY ANCIENT NUCLEUS, WHICH HAS ONLY RECENTLY BEEN CONNECTED WITH THE CONTINENT BY THE FILLING OF THE GANGES TROUGH.

deep roots of the relatively light rock, granite, sunk in heavier basalt, so that the mountains might be thought to be floating, like icebergs. Definite proof of the explanation is difficult and there has been much controversial discussion of the "roots of mountains" or Airy theory and the alternative suggestion, the Pratt theory of balanced masses. Airy's view has for several decades met with little favor among geodesists, but it has of late gained more credence among geologists, and quite recently it has been demonstrated by earthquake waves that the Sierra Nevada of California has a granite roof, at least 20 miles deep. In connection with the uplift of Tibet we may only say that a melted root would be lighter than a solid one, and the effect would be to float the plateau.

Proceeding from this inference, from which we deduce the effect of metamorphism of the under side of the crust or of some deeper layer forming the cover of the molten body, we may next inquire whether the movement of the mountains has been in the direction in which metamorphism should push.

According to the general inference formulated by Suess the arching progresses outward on the convex side of the mountain arc, southward in the case of the Himalayas. There in the foothills of the mighty range geologists have long recognized the fact that the heights are moving forward over the lowlands. It may be that the lowlands are being pushed northward under the heights and that the zone of extraordinary thrusting of sheet upon sheet of rock is being actively squeezed from both sides; but that possibility does not invalidate the evidence of southward movement of the Himalaya mountains, outward from Tibet.

Turning our attention to Turkestan and the Tarim Plateau we there see the arc of the Tianshan presenting its convexity toward the north, as if pushed out from the Tarim basin; and grasping the whole setting of Tibet and Turkestan in our view, we see that between the two apparent centers of expansion, Tibet and Tarim, stretches the nearly straight range of the Altin Tag, which thus lies in the zone of pressure from both sides.

The interpretation of these facts, according to the hypothesis of Metamorphic Orogeny, is that there is a hot spot under each of the wide plateaus and that the disc above the heated layer is expanding in consequence of the elongation of crystals in the process of metamorphism. The width of the Tarim basin is about 350 miles and that of Tibet exceeds 500 miles. Very moderate changes of crystalline proportion would satisfy the requirements of the displacement of the mountain zones, including both the take-up in folding and the over-thrusting of the folded masses, provided that each of the discs had expanded all over and had pushed away from their common boundary in the Altin Tag; but uniform action is very improbable. We shall come nearer to the facts if we assume that the hot spot comprises a variety of conditions, ranging irregularly from molten to pasty solid, and that the effects of recrystallization have been correspondingly unequal in different areas.

A zone of very intense action is found southwest of the Tarim basin in the northwestern Himalayas, where the peaks of the Karakoram range stand as the highest in the world, exceeded only by Mt. Everest, at altitudes of 27,000 to 28,000 feet. Their sculptured pyramids are residual heights, whose pedestal is the plateau that extends from their feet at about 15,000 feet. Their alignment in a northwest-southeast direction in a nearly straight line is that which a mountain trend should have if it were raised by pressure from the Tarim side, and the intensity of compression would result

from expansion of that oval disc in the direction of its major axis.

Thus it seems as though Metamorphic Orogeny might work to produce the pattern of the mountain ranges of the part of central Asia that includes the highest and most extensive plateaus and mountains of the world, and that it offers a force adequate to the task of lifting the vast region to its actual altitude and of compressing the mountain zones. It suggests that the present repeats the past in so far as the uplift of continental plateaus, the upthrusting of mountain ranges and the subsequent erosion of highlands to graded plains have again and again followed the development of molten bodies beneath the outer crust of the earth, in consequence presumably of local, radioactive heating. It answers the three questions: What is the force that is stronger than gravity? What is the horizontal force that wrinkles the face of Mother Earth? And what is the relation between the two?

The claim of the theoretical process to the degree of *Working Hypothesis* seems strengthened. Yet so long as it rests upon the inference of subterranean melting, without more adequate demonstration of that basic condition, it must remain on trial. The Japanese Archipelago seems to be a hot spot. Perhaps a study of the dynamics of that region might lead further.

However, before we go to Japan, where we meet not only the problems of Asia but also those of the Pacific, it may be well to try to decipher the history of the continent according to the hypothesis which we entertain as an explanation of its nuclei and mountain arcs. Our major postulate is that the granitic layer of the earth's crust which we call Asia has been built up by numerous eruptive bodies, that have risen here and there from within the globe, at intervals of a hundred million years or so during the last two billion years. Any eruption may have produced a notable granitic nucleus. Any nucleus may have been the seat of repeated intrusions. The margins of any nucleus may have been the preferred path of ascent of later intrusions from the same source as that which yielded the earlier one. A small nucleus may have been like Ceylon; larger and presumably complex ones are now represented by Angara, Gobi, India, etc. At any given time during the growth of the archipelago the spaces between the nuclei were troughs, through which sea waters flowed and in which sediments were deposited.

This major postulate is supplemented by that of metamorphic orogeny, which we have applied to the development of the mountain arcs. How does that hypothetical explanation work when tested against the arrangement of the nuclei and their sequence, so far as we know the facts? Can the processes have produced the pattern of the wrinkles of continental Asia?

Angara and Gobi are among the oldest of the nuclei. Each of them had a long, early history, which we can not yet read in the confused and distorted masses of ancient, metamorphosed rocks. Whatever the mountain ranges of those remote ages may have been they are now ghostly visions of the imagination. But around the nuclei there remain distinct traces of younger mountain trends, which envelop Angara on the east, south and southwest and border Gobi on the east and southeast. Between the two stretch several ranges, whose alignment is attributable, it would seem, to the expansion of either one against the resistance of the other. Granite intrusions of as late a date as the Paleozoic era and mountain folds apparently related to them occur in the Gobi region and around its margins. These curves are predominantly convex toward southeast and south, but the little Ordos nucleus exhibits evidence of a push to-

ward the northwest as well. In central Asia the general east-west trends are seen to be composed of arcs which frame the nuclei of ancient rocks, but which by their height and youthful sculpture show that there has been mountain-making action during comparatively recent geologic periods. The effect, when interpreted according to Suess's concept of an advancing curve, indicates that each nucleus has been a dynamic body, pressing against adjacent masses, while the general resultant was an outward thrust, southward and southeastward.

Marine strata of Paleozoic ages which are folded up in the bordering ranges around the nuclei of central Asia indicate the former existence of deep and more or less connected or interrupted straits between the islands. During the ages of the succeeding Mesozoic era, for more than a hundred million years, there stretched across Asia and Europe a long narrow sea, called the Tethys, a sort of long Mediterranean. In Asia it occupied the region which is now Tibet and extended to the east and west. Sediments accumulated in its waters to the depth of many thousand feet, and it is obvious that the crust of the earth was depressed or sank below some previous level to great depths and also that it has been raised during later times to its present height. According to the hypothesis which we are considering the subsidence may be attributed to slow cooling, solidification, and shrinkage of volume of the sub-terrane beneath the Tethys, while the uplift during later periods follows from subsequent meltings and consequent increase of volume, as we have suggested in the earlier pages. Interacting with two or three epochs of melting and uplift or occurring in sequence between them (the details of dynamic relations are not yet clearly read) there occurred activities of folding. Strata of Jurassic and Cretaceous ages of the Mesozoic era are intensely folded in mountain ridges that traverse the plateau of Tibet. They once formed ranges of greater relative height above the plateau than they now exhibit; but they were eroded and the plateau surface was planed by erosion to a graded landscape of broad valleys before the whole mass was raised to its present altitude. In the meantime the basin of Szechuan, which also was part of the Tethys trough and was filled with sediment, has remained depressed or has subsided in recent times, while Tibet has been pushed up. These various and diverse movements can not be explained by any simple mechanical action of pressure from an extraneous source. They seem to demand internal activities, originating within each nucleus in the lower part of the rigid crust and operating to expand the area in such manner as to cause the margins to be thrust outward. The hypothesis of repeated melting and metamorphism is framed to meet these requirements.

TO WHAT EXTENT IS A SCIENCE OF MAN POSSIBLE?

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I

KNOWLEDGE of man has been growing slowly over thousands of years. But a science of man is something new under the sun. For though science is knowledge, it is a special kind of knowledge. It is obtained by scientific methods, usually involving a collaboration between theory and experiment. Most science is based on the quantitative analysis of measured phenomena. It differs from other knowledge chiefly in its quality of being demonstrable. An experiment to have scientific value must be one that can be repeated. Scientific phenomena can be measured and recorded over and over again or related by theory to other phenomena that can be repeated. New knowledge of this sort becomes generally accepted when it has been checked over by a sufficient number of people. The older type of knowledge which is derived from personal observations and the conclusions of authorities is harder to check up on, is more subject to personal bias and the mental fashions prevailing at any given time. Scientific knowledge, on the other hand, is cumulative in its effect and has a known predictive value.

In a hundred thousand years, by his use of the old forms of knowledge, man developed an environment suitable for a civilized life. He domesticated animals, produced cereal crops, and through the great religions aspired at least to a noble concept of the dignity and character of life.

Then, in a few brief generations, the new forms of knowledge which we call science brought to men a marvelous control of their environment—railroad, telegraph, telephone, electric light, motor car, submarine, aeroplane, radio, television, reduction of labor needed on the farm, canned and frozen foods, cheap goods by mass production, sanitation, medicine and public health. Almost over night the natural and physical sciences have brought these changes.

The biological quality and the training of man has not undergone comparable changes. Except for medicine, we know so little about man that it is still fair to ask, "Can we have a science of man?" And the question is, somehow, troubling. Man's new power to control the environment has not made him humble. He seeks new short cuts to happiness. The older knowledge of man, heritage of ages of experience and suffering, he tends to discount, because it is not based on the new scientific method, not capable of scientific proof. He is not likely to go back permanently to the old knowledge. He is too impatient of its restraints, too admiring of the success of the new type of thinking based on the scientific method. Yet without more knowledge of himself, of his needs, his weaknesses and his possibilities, we may wonder whether man can safely handle the extraordinary tools he has recently created. They may inflict irreparable injuries. If we ask, "To what extent is a science of man possible?" perhaps we are really asking to what extent can we achieve a secure and permanent civilization?

It is hardly encouraging to compare the present state of the science of man with the marvelous development of the natural

sciences. But the picture is a more hopeful one if we make allowance for the respective ages of these two fields of science. Several generations of men have been trained and taught in the physical sciences. But no one of the age of forty-five or more to-day could have had any serious training at college in the sciences that have to do with man. They were not available for teaching twenty-five years ago, which is a pretty brief span of time, even in this hurried age.

Scientific work in psychology was in its infancy at the turn of the century. Mendelian genetics were rediscovered in 1901. At about the same time anthropologists got out of their armchairs and began collecting ordered data in the field. By 1910, text-books were beginning to make significant use of new scientific materials in these fields. By 1920, courses in scientific psychology, genetics, human biology and anthropology were available in most of our universities. To-day these subjects are among the most popular of any that are offered. But much that is taught about man and society is not science. Not enough research has been done to supply the basic material needed; and, still more important, there has been too little time for critical analysis, interpretation and organization of the research that has been already carried out. Notwithstanding this present handicap, the sciences of man have already begun to influence our thinking in a way which suggests the effect that they may have in the future when they are more fully developed. A few examples will make this clear.

II

Psychology has made important contributions to present-day points of view. There are some two thousand registered psychologists in the United States to-day, where there were only a few scattered individuals in 1900. The sum total of their research fills innumerable volumes. But much of this research has been badly done, as would be expected in so new and difficult a field.

Some of the most important work in psychology has been that on the development and experimental application of psychological measures, which are the necessary tools of acceptable research. Methods of measuring intelligence have been used extensively and criticized and refined during the last twenty-five years. Their weaknesses and limitations are now fairly well recognized and understood. In the hands of competent psychologists they have given us what little scientific knowledge we have concerning the origin and development of the faculty of intelligence which most distinguishes men from other forms of life.

There is still controversy among psychologists; part of this may be described as a controversy between older schools of psychologists and those trained during the last decade. Laymen who engage in controversy are often found to be leveling their lances against concepts and methods that have been completely discarded by critical contemporary psychologists. Much of this controversy relates to the roles of heredity and environment in the development of intelligence. Recent work goes far to clarify this difficult field. In the past few years, the so-called fixity of the I. Q. has been disproved. We know now that a stimulating environment in the home, in pre-school, in elementary school, in high school, in college and in later life tend to raise the I. Q. of an individual, and to maintain it at a higher level. We know that in a depressed environment intelligence fails of a normal growth. A child of two with apparently normal intelligence may in the unstimulating surroundings of a badly run orphanage revert to feeble-mindedness. On the other hand, there are important differences between individuals

in the extent to which they respond to the stimulus of the same environment. Individual differences do not disappear when the environment is equalized at a high level. In a stimulating environment, able individuals show a capacity for response which takes them further than ever out of the class of those of average ability. Among Newman's 19 pairs of identical twins reared apart, there were 11 pairs in which the two members of each pair had had similar amounts of education. In each such case the twins differed in I. Q. only about as much as the same individual would vary when tested at different times, the average of differences being 4.4 points. Among four of the pairs there was considerable difference in schooling between the members of each pair; their I. Q.'s differed on the average by 10 points. Among the four remaining pairs, educational differences between the members of each pair were large, and in these four cases the twins differed by 19 points, on the average. In every case the twin with the more education had the higher I. Q. But at the same time where one twin was dull for his poor environment, the other was dull for his good environment, and where one twin responded well to his poor environment, his mate responded well to his good environment.

Twin Eleanore only got as far as the fifth grade, and attained an I. Q. of only 66. Her sister Georgiana went through grade school, high school, four years of music and three years of normal school. After all that education, her I. Q. was only 78. It is hard to escape the conclusion that this pair of identical twins were not endowed with the genetic factors necessary to ordinary intelligence.

Twin Gladys, with only three years' elementary schooling as the total of her education, had the creditable I. Q. of 92. Her sister Helen, with a college degree, had an I. Q. of 116. Evidently the genetic endowment of these girls was sufficient for the development of average intelligence.

The findings on identical twins reared apart check pretty well with other studies on the relative contributions of heredity and environment to individual differences in intelligence in the general run of our population. Of course, nineteen pairs collected by Newman and one by Muller is a number woefully inadequate for statistical validity, but this inadequacy is typical of the present state of the science of man.

If heredity is indicated as an important factor in differences in the intelligence of individuals, this is far from being the case with respect to differences in average intelligence which are found between socio-economic or occupational groups. There have been five studies of foster children in which it was possible to distinguish the occupational or socio-economic grouping of their true parents. These are the studies by Burks of California, by Freeman of Chicago, by Leahy in Minnesota, by Skeels in Iowa and by Lawrence in England. In the Freeman and Skeels studies there is evidence of selective placement. That is, the brighter children were more often than not placed in the superior homes. In the other studies this was apparently not the case. The findings from all five studies were similar. The children whose true parents were in the lowest occupational or socio-economic groups had an average I. Q. about 6 points lower than that of the children whose true parents were in the upper occupational or socio-economic groups, the foster homes being in all cases carefully matched for educational stimulus. This difference of about 6 points indicated as the contribution of heredity is small, and becomes even less significant on further analysis of the methods necessarily employed in these studies. If it had been possible to set

these studies on a better basis, it is likely that an even smaller difference would have been shown. If these are the indicated differences between the relatively small group at the bottom and top levels respectively, then the differences in hereditary capacity between any of the larger groups are of little importance. As in the case of identical twins, the number of studies is quite inadequate for final conclusions. But even these tentative findings point to some interesting inferences.

If innate differences in intellectual capacity are on the average so small between different occupational classes, then our educational system should not be permitted to become a class affair. The American ideal that would open the highest educational opportunities to young people from every rank of society would seem fully justified. On the other hand, if hereditary factors are of major importance in determining differences in intelligence between individuals in a similar environment, then our educational system should be pointed up to meet the needs of individuals at different levels of genetic capacity.

Thus, the recognition of individual differences shows the need for the separation of the sub-normal from the intellectually superior in their class of work if either group is going to benefit fully from its education. The beginning of such a separation is being made in some schools to-day. It is one of the important contributions made so far by the budding science of man. This process of fitting the education to the capacities of the individual will undoubtedly continue as our educational system becomes increasingly affected by our growing knowledge of individual differences in capacity.

III

In the field of genetics, the marvelous advances of the past forty years have been largely limited to the genetics of plants, insects and animals. For some reason, human genetics has been largely neglected in this country compared to what has been done by Fisher, Haldane and Hogben, in England, and by Verschuer and others in Germany. There is almost no knowledge of genetic factors in normal variations in general qualities, such as intelligence, character or susceptibility to disease. Important work has been done on blood groups. A considerable number of infrequent abnormalities are known to be due to genetic factors, and in some cases the mode of inheritance is known. Research work on genetic factors in feeble-mindedness and in mental disease is almost all in the future. Nevertheless, there are many signs of an aroused interest in the medical profession and a new recognition of their responsibility for preventing the spread of serious hereditary defects.

Ultimately, scientific knowledge in regard to the part played by genetic factors in causing individual differences, and further research on the inheritance of different genetic factors, may make possible measures that would tend to discourage the reproduction of inferior genetic strains and encourage the reproduction of those above the average.

Thus, scientific knowledge of the relative parts played by heredity and by environment in developing individual differences may become a valuable tool for improving human qualities, first on the environmental side through changes in education and ultimately through raising the average hereditary level.

IV

Anthropology has made at least one important contribution to the American point of view by showing the extent to which culture patterns are fixed by the social environment with little regard to the type of people involved. Many of the

qualities commonly spoken of as "racial characteristics" are now known to be matters of social rather than genetic inheritance. The whole concept of race has undergone a violent transformation in the past fifteen years. It is said that Hitler during the two years he spent in jail before coming to power read widely in what were then supposed to be scientific books dealing with race. They were not scientific in our present definition of the term: they were the German analogies of Madison Grant's "Decline of the Great Race," which was having a vogue in this country at that time. Modern research of a more scientific sort denies most of their conclusions. It is interesting to speculate on what would have been Hitler's attitude towards race if he had had access to present scientific knowledge.

These few and tentative conclusions are suggestive for the future, but they do not indicate to what extent the science of man may be possible. It is only very recently that we have really lifted age-long taboos against an honest examination of ourselves. In the past twenty years more of a start has been made than might reasonably have been expected under the circumstances. The prospect for the future seems hopeful. The extent to which we can have a science of man would seem almost unlimited provided three major conditions are met:

The first is plenty of time.

The second is the enrolment in this work of men of high abilities, with adequate support.

The third is freedom of thought, freedom of inquiry and freedom of criticism.

V

Research problems concerning man are, in many cases, no different in kind from research problems concerning other forms of mammals on which effective work has been done. But the problems of man are infinitely greater in complexity and require more time in proportion as the space between human generations is longer than the space between the generations of the smaller mammals. What Tryon learned about the genetics of maze-running ability in rats might be duplicated in human beings with regard to genetic factors in differences in general intelligence, but it would take 200 years and a quite inconceivable control of human breeding to carry out such an experiment. The difficulties of studying environmental influences are almost as great, but there is no reason to believe they can not be solved by sufficiently persistent effort and by the development and application of new methods.

There remains one important difference between the study of animals and the study of man, namely, that in the latter case man is studying himself and thus finds it more difficult to exclude his personal and emotional biases and reactions. It is for this reason, among others, that freedom of criticism is as important as freedom of thought in the development of the science of man. With all these difficulties taken into account, there is still every reason to believe that the development of the science of man will go forward rapidly from its present modest beginning.

VI

It is worth while to consider the different practical applications that may result from the sciences of man. The first has to do with education. Present methods of education are the product of a long evolution under the guidance of the old type of knowledge. On the whole, education to-day is undoubtedly better then the education available in the past. But we do not know in any precise way what a modern education really does or the different effect it has on different types of people. Psychologists in great number are working on new measures for deter-

mining individual capacities along different lines. Other psychologists are trying to determine the effect of different educational environments on people of different capacities. We may be sure that there is no single environment that would be the optimum environment for every one. Each individual will make his maximum development in the environment that will most stimulate the particular responses of which he is capable. The environment that would be optimum for a dull person would be insufficient for the full development of a superior person. In the studies on orphanage and preschool children being made by Stoddard at the University of Iowa, the brightest children showed the least growth in the deprived environment of the orphanage. The Pennsylvania Inquiry on school and college education by the Carnegie Foundation indicates wide individual differences in ability to respond to a college education. A considerable proportion of those going to college go backwards rather than forward intellectually during their last four years of schooling. It is not too much to hope that work of this sort will develop a science of education such that ultimately we shall be able to measure the specific potentialities of each individual and provide an educational environment which would be the optimum for each of his particular abilities. Such a change in our educational system if universally applied would probably raise the average I. Q. almost 20 points. Few people would remain without some specific capacity which, properly developed, would make them more valuable members of society in their own recognized specialty.

With respect to the development of character and a balanced personality, scientific advance is more difficult than in the field of intelligence, but work is now going forward which will hasten the revolution in our treatment of criminals, and which will ultimately greatly reduce the number of anti-social, distorted and unhappy personalities; and even for the normal child will make possible a more socially adapted and happier personality.

VII

To date, the most effective applications of a science of man have been in medicine, nutrition and public health. The expectation of life at birth is now double that prevailing a century and a half ago, and has been increased from 49.2 years in 1900–1902 to 60.3 in 1929–1931. Medicine had a long start on psychology. It is not unreasonable to suppose that in another fifty years we may have a science of man which can prescribe the optimum environment not only for the maximum physical but also for the maximum intellectual and personality development of each different individual. The application will not be easy. But when the knowledge is available, some way will be found to apply it.

The science of human genetics will ultimately supply psychologists with additional knowledge necessary for an understanding of different human types. But the major applications of the science of human genetics will be in the field of direct improvement of the genetic qualities of human stocks. That is far in the future. What a few men did in twenty years, working in *Drosophila*, it may take several hundred men a hundred years or more to do working on man. Given sufficient time, and the development of new tools of research which will surely take place, a fairly complete genetics of man is possible. Whether its practical applications will be important, I leave to you to decide. Does your experience in plant and animal genetics lead you to think that the average man's socially valuable qualities in our changing environment could be improved by creating conditions in which superior strains

have the larger families and in which the breeding of inferior strains is effectively discouraged?

VIII

We have been considering only the sciences relating to individual differences and individual development, and the contributions which these sciences may make to the improvement of human beings. But the study of man can not proceed independently of his environment and his activities, which are the field of the so-called social sciences. Nor can the social sciences proceed successfully without more knowledge of this strange and complicated creature, man. The development of the science of man should therefore have another important effect in the contribution it will make to the sciences which deal with the behavior of men in the mass and their relations to each other.

All branches of sociology are at present handicapped by lack of knowledge of the human material whose activities they are studying. The postulate of the economic man, impervious to all other emotions, does not add to the reality of economics. Perhaps the new field of population study provides the best example of the interdependence of studies of man and studies of man's activities. Here the analysis and forecasting of total population trends has been revolutionized since 1925 by the introduction of procedures for taking changes in age and sex composition accurately into account. It is safe to say that the error in population forecasts for the United States for the next thirty years has been cut in half by the application of these techniques, and equally important information about future age distribution has been added, which was wholly lacking before.

The study of the adjustment of the population to resources in different parts of the nation, which had never been given serious attention before 1930, has been developed to the point where its results already have very practical and far-reaching significance. The study of differential reproduction rates, which prior to 1930 had been based chiefly on such fragmentary and inaccurate data as reports by college students about the numbers of children in their fathers' families, has been extended and refined until it is possible to describe the reproductive tendencies of most population groups in the United States with considerable accuracy, and we are now beginning to get accurate information on how these rates are changing in different groups under different conditions. It may be hoped that the 1940 census will supply the necessary materials for far more accurate and extensive studies along this line.

But these so-called group differentials in fertility relate only to occupational groups or to regional groups. We know that farmers have more children than city people, but we do not know what genetic types are surviving in the greatest numbers. It is impossible to say at present on the basis of any scientific evidence whether the human race is improving or whether it is deteriorating. This important question, with all its practical implications, can be answered only when population study can employ measures of innate human qualities, and for these it must wait on the development of the sciences of man.

Thus, the science of man may not only make it possible to improve man himself by supplying the proper environment for his development and, ultimately, even by an improvement in his genetic potentialities, but may give the social sciences sufficient precision to make them truly sciences capable of predicting the end results of current political, social and economic trends.

The sciences of man may in these ways make an invaluable contribution to human welfare. They may also make

an even greater contribution in setting up new concepts of human possibilities, new ideals as to the purpose of life.

IX

In the long period of comparative world peace which lasted 100 years from the Battle of Waterloo to the outbreak of the World War, there seemed to be a growing recognition that the physical well-being and the fullest intellectual and moral development of individuals was the highest goal of society. This ideal of individual improvement was eclipsed by the old barbarism which emerged in the war and by the desperate struggle for power that has followed. We seem to be going back to primitive aspirations in which the improvement and happiness of the individual are subordinated to the power of the state. A return to religion would prevent this trend going further, but a new stimulus is needed. That stimulus may lie in the science of man. When we have a clear picture of what an optimum environment can do for the development of the individual; when we understand better the extent to which inferior genetic qualities may limit human development compared to the full flowering of those with a superior inheritance; when we realize that for each region of the earth and for each stage of its civilization there must be an optimum population at which its people are best supported; when economics and sociology understand the human material with which they are dealing and become in their turn sciences of human relations; when we have in our hands demonstrated scientific tools capable of vastly raising the level of human relationships and of the developed qualities of man, may we then not hope that men will be moved to new aspirations commensurate to their new possibilities? Science will never take the place of religion in revealing the ultimate mysteries and purposes of life—whence we came, our purpose here on earth or what lies beyond. But religion is also concerned with improving the lives of human beings, and hence religion will be strengthened by the sciences of man as they demonstrate methods for attaining a new and higher ideal of man's life on earth. And the demonstration that such an ideal is possible is the first step towards attaining it.

ENGINEERING—ANCIENT AND MODERN[1]

By E. H. HULL

GENERAL ELECTRIC RESEARCH LABORATORY

RECENTLY we have indulged in much back-patting and self-congratulation on our modern engineering progress. Let us go back a few thousand years to see what we have which the ancient peoples lacked. In general we will find that most ancients had a large number of products and devices which we think of as modern. For example, there are now large industries making boards from cornstalks, artificial silk from wood, automobile steering wheels from soya beans, and so on. In the pre-Christian era there existed industries which supplied imitations of things too expensive for the common people, such as metallic alloys resembling silver and gold, artificial pearls, a cheap dye matching the costly Tyrian purple, artificial amethysts and other jewels from glass.

Suppose we hastily review the knowledge of ancient peoples to evaluate their possibilities in engineering achievements. The more advanced races had developed out of the stone age in prehistoric times. They used copper and bronze implements before written history, hardening these soft metals by hammering. By about 1000 B.C. iron was replacing bronze for many uses. Smelting of metals was successfully practiced as well as the metal-forming processes of forging and casting.

Somewhat later steel was made from iron and hardened by quenching in water or case-hardened by baking in charcoal and then quenching. Homer in the "Odyssey" mentions hardening iron by quenching, and in the Iliad he gives a vivid picture of armor-making, using fires, bellows, tongs, hammers and anvil to form gold, silver and bronze into elaborate designs. Some idea of the prevalence of iron in 700 B.C. is indicated by the discovery of 176 tons of rectangular iron billets in the storehouses of the Assyrian king Sargon II.

With these materials, hand tools for all trades were made in numbers and variations nearly equivalent to the present-day list. In certain instances the ancient tools show a more refined design than our modern examples.

For rock-cutting the Egyptians employed copper saws set with corundum teeth capable of working in slabs of rock 7½ feet thick. Core drills set with jewel stones for drilling rock could turn out work which has been judged the quality equivalent of our modern reinvention, the diamond core drill.

The theoretical equipment of the ancients was not great until developed in Greece during the last few centuries B.C. Previously all designs were based on experience and rule of thumb. This is true to a large extent in some branches of modern engineering. It is also true of the Roman engineers after the decline of learning in Greece.

The early Egyptians could do simple arithmetic, and were expert at measuring because of the yearly necessity of resurveying the flooded Nile valley. Despite their lack of theory the Egyptians made some remarkable structures. We have all been awed by the size of the Great Pyramid, but actually size in a structure of that type is just a matter of time, money and tremendous quantities of slave labor. In my opinion the astonishing thing about the Great Pyramid, built in 4700 B.C., is not its magnitude but the accuracy with which it was laid out and built and which it has maintained. One investigator, after careful measurement, has shown the sides to have a mean error

[1] Presented on the W. G. Y. Science Forum.

of only six tenths of an inch in 756 feet. For comparison, a carefully machined part of a modern automobile might be held to within plus or minus one ten thousandths of an inch in a one-inch diameter. This allows an error of 2 parts in 10,000, whereas the pyramid error is only 7 parts in 100,000 or one third as great.

An examination of the chambers in this pyramid shows that many of the seams between blocks of stone are nearly invisible, and that there are no signs of settlement cracks or flaws. One wonders whether any of our modern structures will survive 6,600 years in as perfect condition.

Flood control sounds like a modern problem, at which we have not done too well—witness the 1937 Mississippi River flood. Herodotus, a Greek visiting Egypt in 430 B.C., described a flood control and irrigation system in the Nile valley which was begun in 3400 B.C. This system contained a dam impounding a water area of 700 square miles connected to the Nile by canal, for regulation purposes. The river valley land below this dam was divided into basins for holding the water until the silt used for fertilizer had settled out. Villages were built on artificial mounds above flood level. Instead of dreading floods the Egyptian farmer welcomed them, since the silt brought down by the flooding river was necessary for enriching the land.

As I mentioned before, the Greeks were the first people to contribute largely to scientific and engineering theory. By 200 B.C. plane and some solid geometry was pretty well worked out, the laws of levers and center of gravity understood, and something was known of relative density and hydrostatic pressure. In fact, plane geometry was called Euclid, after the Greek scholar, until quite recently. Physics books now name the law of buoyancy after its Greek discoverer Archimedes. The Greeks also had some understanding of the arithmetical relations of musical tones and the laws of light reflection. Archimedes had determined the value of π, that is the ratio of the circumference of a circle to its diameter, to within 1 part in 10,000.

At the height of the Greek civilization, the great minds were almost entirely concerned with theorizing. Practical applications of their new knowledge did not interest them; in fact, practical engineering was considered beneath their exalted station. This attitude is not unknown at the present time. As there was plenty of cheap slave labor to do the job required in the Greek world no need was felt for labor-saving or power-producing machinery. The building of automata, similar to our mechanically operated toys, was as near as these scholars cared to approach practical application, although they were not above loading dice with lead, as mentioned in the writings of Aristotle.

With this background many interesting but non-productive devices were built. Greeks used water trickling through a small hole into a reservoir as a measure of time. These timepieces had many ingenious variations such as a form of alarm clock attributed to Plato. In this device a second closed reservoir was connected to the first by means of a siphon which would not become charged until the water in the first reservoir had reached a predetermined height. The siphon would then quickly draw off the water from the first reservoir to the second, forcing air out of the second reservoir through a whistle in the cover. There is a mechanically operated puppet theater described, which is a good example of an automaton, built to mystify the common people. This device consisted of a closed box set on wheels running in tracks laid on a stage. On top of the box was a small temple surrounded by figures of dancing girls and containing an image of Bacchus. The device

moved onto the stage under its own power while Bacchus poured libations and the figurines danced. At the conclusion of the performance the wheel-driving mechanism reversed, moving the entire show off of the stage. Power for this contrivance was obtained from a falling weight hidden in the box and controlled in speed by a device similar to a water clock, but using millet seed instead of water.

When necessary the Greek scholars could do outstanding engineering work. Archimedes was drafted for the defense of his native Syracuse against the Roman fleet and armies. The historian Polybius describes several of Archimedes' new devices designed for the destruction of the Roman galleys operating under the city walls. One employed a heavy lead ball, suspended by a pulley arrangement from a long arm, which could be swung about and dropped on the galleys' decks. Another device suspended a grab hook from a crane arm in such a way that the hook could catch the bows of the Roman ships, lifting and suddenly releasing them, causing a "scene of the utmost confusion," to use a phrase from our historian.

At the end of the pre-Christian era we find more attention paid to practical devices containing the so-called modern machine elements such as wedges, jack-screws, pulleys, windlasses, levers, toothed gearing, etc. Compressed air and hydraulic devices such as force pumps, siphons and pipe organs were known also. Hero or Heron, an Alexandrian engineer, describes several useful machines, among them a hodometer similar to our bicycle odometers. Hero's device, when mounted on a wagon, converted the revolutions of the wagon wheels, through suitable step-down worm gearing, to distance traveled, and showed this distance on a calibrated dial. For use as a taximeter, metal balls were arranged to be dropped by the machine into a resonant container, thus marking the completion of each unit distance of travel with a suitable noise.

Hero also describes a two-cylinder water pressure pump for fire extinguishing, fitted with a nozzle capable of pointing in any direction. Remains of pumps similar to this have been found, made of wood with lead-lined cylinders. Other two-cylinder pumps, made entirely of bronze, have been recovered. The pump valve designs are quite satisfactory for modern use.

Hero is credited with a device resembling a reaction steam turbine. He mounted a hollow bronze ball on pivots between two uprights above a heated closed vessel containing water, that is, a boiler. One upright and pivot was made hollow so that steam could be led from the boiler into the hollow ball. This steam escaping from two bent nozzles on the ball rotated the ball. Since power could be cheaply obtained from slave labor this device was looked upon as an interesting toy rather than a source of useful power. It wasn't until seventeen centuries later that men became seriously interested in using steam for power purposes.

Hero's surveying instrument, the dioptra, contained all the essential movements of the modern transit without its telescope. A water level with a long base built into this instrument gave accurate leveling. The familiar surveyor's staff with movable sighting disk was used in its present form.

On the water the ancients got around quite well. About 600 B.C. the Phoenicians circumnavigated Africa. Later there was a canal from the Nile to the Gulf of Suez serving the same purpose as the present Suez Canal. Apparently the ancients were troubled with some of the same problems which our modern naval architects face. The early boats on the Nile were built with long, overhanging bows and sterns. To prevent

sagging of these portions a truss of twisted cable was passed from the bow over several short uprights set along the length of the boat and again fastened at the stern. This anti-hogging device can be seen on some modern river steamboats as a steel rod with turnbuckles placed exactly as in the Egyptian boats.

In the Mediterranean the Greek and Roman war galleys could attain speeds of 13 to 15 knots for short times and average 7 knots on long voyages. In maneuverability these galleys have never been surpassed. Again man power was used to propel these vessels since it was easily obtained and controlled. Only on long voyages with favorable winds or in merchant vessels were sails employed.

Some of the ancient ships were rather large, a galley built for Ptolemy Philopater of Egypt was reported to measure 420 feet long on a beam of 57 feet. A dry dock complete with movable gates, valves, pumps and keel blocks, is described for handling this mighty ship.

There are many more instances of the ancient use of modern discoveries and reinventions. Theophrastus (third century B.C.) describes coal and its combustion. Dioscorides (first century A.D.) mentions the distillation of crude mineral oil to obtain different grades of oil. Apparently our modern petroleum industry began its development at least 1,900 years ago. We think that certainly our chewing gum and cigarette vending machines must be new, but Hero describes a device for dispensing ceremonial water in Egyptian temples, operated by putting money in a slot. The advantage of the ancient device over ours was that the exact coins were not needed, since the machines delivered when the correct total weight in coins had been provided.

Ingenious and modern-sounding as many of these early devices are, they differ from our modern engineering projects in that they take no account of power. The ancients employed cheap and easily available slave labor, which could produce about one tenth horsepower per head. While this system was all right for the ruling classes, for the slaves themselves it meant untold labor and suffering. Great as have been our advances in science and engineering, they are more than paralleled by our social advancement. And perhaps the ancient engineers, if they could come to life today, would be most surprised to see us using, instead of a sweating and groaning slave, his power equivalent of 75 watts of electricity, which most of us can buy at the rate of two fifths of a cent an hour.

BAKING TECHNOLOGY AND NATIONAL NUTRITION

By Dr. JAMES A. TOBEY
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BAKING has been an art since the dawn of civilization, for bread is the most venerable of the prepared foods of man. In every era of harried human existence, the race has been nurtured, biologically if not spiritually, on bread alone. Thus, bread has come to be an appropriate symbol for food itself.

It is an apt symbol, because bread gives sustenance that satisfies certain important physiological needs. While it is axiomatic that there is no substitute in the human diet for pure milk, foremost of our protective foods, it can be asserted with equal scientific validity that there is no substitute for good bread, foremost of the foods that give energy. Research has amply demonstrated, in fact, that the most beneficial diets are usually those that are built around bread and milk.

From a craft, baking has been emerging in recent years into a science. There has been developing a new baking technology, based on the application of scientific methods and principles to the age-long art of bread-making. The progress of this new technology is, of course, far from complete, but already its results have had a definite influence on our national nutrition.

The future influence of baking technology will depend not only upon the significance of new discoveries and procedures, but upon their avid application by the baker and, most of all, upon the ability with which they are interpreted to the consumer. In any branch of technology, interpretation is always as important as investigation and application.

THE SCOPE OF BAKING TECHNOLOGY

Baking technology begins not in the bake shop or the mill, but on the farm and in the soil where wheat, the aristocrat of the cereals, is produced. It is to the cereal chemist that we must look for the first step in the ultimate manufacture of the perfect loaf of bread. Where the cereal chemist leaves off, the bakery engineer begins, although the line of demarcation between the responsibilities of the two is sometimes difficult to define.

The cereal chemist is concerned primarily with the properties of flour, the principal ingredient of bread and baked goods. In most instances he is a laboratory technician, remote from the consumer. It was suggested by L. E. Caster at the 1938 meeting of the American Association of Cereal Chemists that most cereal chemists would perform more valuable functions if they spent considerable time in the operating end of bakery production.

"Cereal chemistry," said Mr. Caster, a former president of the American Society of Bakery Engineers, "is still in the pioneering stage. The chemist has been prone to tackle his problems from a pure chemistry standpoint and has forgotten that flour is a biological, living material which changes from day to day. In order, therefore, to be of assistance to the production man, the chemist must realize that he, in the laboratory, must deal with flour and bread just as they are produced and used, not for the purpose of running his chemical determinations."[1]

[1] L. E. Caster, *Am. Baking Ass. Mo. Bull.*, May–June, 1938.

The problems of baking technology are accentuated by the fact that wheat and the flours made from it in different years and in different places seldom show any degree of uniformity. These variations are due to certain uncontrollable factors, such as climate and weather, but they are also due to some controllable factors, such as soil chemistry, plant genetics and methods of harvesting. The miller is cognizant of these problems and cooperates with the baker in attempting to solve them.

Modern Bread

Modern bread is, however, more than wheat flour. A quarter of a century ago, bread was made largely in the home from wheat flour, salt and water, fermented with homemade yeast of somewhat uncertain quality. To-day, about 85 per cent. of all bread consumed in the United States is prepared by approximately 28,000 commercial bakers. The formulas employed by these bakers not only are different from those formerly used in the home, but they are better, and here is one important advance in baking technology.

In addition to wheat flour, the modern baker of white bread also includes milk solids, pure yeast of uniform quality, some kind of shortening or fat, salt, sugar in the form of sucrose or dextrose, malt or malt extract and water. Where local water supplies are too soft, he may add very small amounts of certain calcium salts as dough conditioners. Because of the richness of his formula in other ingredients, the baker uses slightly less flour than was once the custom. The resulting improvement in the quality of the loaf tends, however, to increase rather than decrease flour consumption.

Perhaps the most significant change in the formula of modern white bread has been the inclusion of increasing amounts of milk solids, derived from whole or defatted liquid milk, condensed milk or powdered milk. The growth in the use of milk in bread is indicated by the fact that in 1923, when the American Institute of Baking took the initiative in advocating more milk in bread, the baking industry purchased 33,000,000 pounds of dried skimmed milk, as it was then called. To-day, bakers buy more than three times that quantity of "dry milk solids not over 1½ per cent. fat," as the product is now more aptly designated. The baking industry is, in fact, the largest single customer of the dairy industry, procuring annually from it the equivalent of a quarter of a billion quarts of milk.

The addition of milk solids to bread is important from both the standpoints of baking technology and dietary quality. The use of milk in bread unquestionably improves its color, texture, symmetry and general quality, without appreciably affecting the cost per pound. The milk contributes complete proteins, which supplement the nutritive properties of the wheat proteins, glutenin and gliadin. Bread made with milk has, in fact, about 10 per cent. protein, which contains all the amino acids now recognized as indispensable to life.

Milk solids likewise contribute the important food minerals, calcium and phosphorus, to bread. The presence of these minerals in white bread is further augmented by the use of calcium salts as dough conditioners or so-called yeast foods. Modern bread is, in fact, a much better source of calcium than published analyses of the past would indicate. Recent investigations by Cathcart and Prouty in the laboratories of the American Institute of Baking at Chicago have shown that commercial loaves of bread will average .065 per cent. calcium.[2] Thus, six slices of bread a day will furnish 30 per cent. of the calcium requirements of the normal adult. A pint of

[2] *Jour. of Nutrition.* In press.

milk in the diet would supply the remainder.

The use of an average of 6 per cent. milk solids in white bread has served likewise to make even more ridiculous and absurd the rantings and ravings of the food faddists who wax so frenetic over the alleged virtues of whole wheat products and the supposed deficiencies of white bread. The routine addition of milk to white bread (except French and Italian bread) has so narrowed the nutritional gap between this nourishing food and the coarser-grained dark breads that the only dietary advantages now recognized for whole wheat bread are the higher contents of iron and vitamin B_1 or thiamin. The higher contents of these nutrients are offset somewhat by the fact that whole wheat products also contain a large amount of indigestible, unassimilable fiber or roughage. Bran may be a boon to a few sufferers from chronic bowel dyskinesia, or constipation, but for many persons it is a dangerous irritant in the gastro-intestinal tract.

Restoring Lost Nutrients to White Bread

White bread made with milk is a fairly good source of vitamin B_2 or riboflavin, but it contains only from one fifth to one fourth the usual thiamin or vitamin B_1 content of whole wheat bread. Since this important factor is frequently deficient in the average American diet, its preservation in refined flour and white bread or its restoration to these products would be eminently desirable. Despite the ardent pleas of nutritionists for a greater consumption of the whole grain products, the American public always has preferred white bread and continues to espouse it, chiefly because of its bland flavor and more attractive appearance. Only about 2 per cent. of all wheat flour now consumed in this country is of the whole wheat variety, and there seems to be little likelihood of any drastic increase.

Modern baking technology has developed effective methods for the retention of thiamin in white bread, although these procedures are not yet in universal use. Thus, new methods of milling are reported as preserving the original content of vitamin B_1 in white flour. Ingredients rich in this factor, such as yeast, have also been placed on the market, and there are available various concentrates of the vitamin that can be added to the dough. Since thiamin is thermostable, there is no appreciable loss of it in baking.

Here, then, is an opportunity for the baking industry to improve still further the nutritive qualities of the staff of life. Once these methods of restoring a lost vitamin to bread are on a satisfactory economical basis, they deserve wide adoption. Such methods will not make bread a perfect food, but they will enhance its dietary values.

Research in the Baking Industry

Since the baking industry is a local service industry, comprised of a large number of small companies, and since there are relatively few big concerns with adequate facilities for laboratory investigations, research in the field of baking technology is primarily the duty of the organized industry itself. Such research is undertaken by the American Institute of Baking, the scientific and educational agency of this food industry, at its laboratories in Chicago.

Among the important problems that have received attention and are now being investigated are improvement of the quality of the loaf through the use of baking pans of proper dimensions; the prevention or postponement of the apparently inevitable staling of bread; the improvement of bread flavor; the sanitary protection of custard and cream-filled baked goods by pasteurization and other methods; the chemical and physical

properties of dough; the cooling and wrapping of bread; photo-electric methods for determining the characteristics and quality of bread crumb; and means of scoring and tasting bread.[3]

A recent advancement in the laboratories of the American Institute of Baking has been the development of a successful process of preserving bread by freezing.[4] While this device has not yet received much practical application in ordinary commercial usage, it is being considered for such purposes, and the process might assume real importance in time of war.

In addition to the studies on baking technology conducted by the institute itself under the able direction of Dr. W. H. Cathcart, the department of nutrition of the American Institute of Baking has made available grants for research fellowships at leading universities for studies on the nutritional aspects of bread and bakery products. Such fellowships have been established at the Massachusetts Institute of Technology under Professor S. C. Prescott, and at Columbia University under the direction of Professor Henry C. Sherman. These ivestigations and others of a similar nature will be concerned with the chemical, biochemical and biological properties of bread and their influence on human nutrition.

Bread in National Nutrition

The improvements in the dietary and gustatory qualities of bread and bakery products that have been achieved and are being accomplished are of distinct significance to our national nutrition. As a necessary foundation for the protective foods, the energy-giving food, bread, may properly constitute as much as 40 per cent. of the calories in a well-balanced daily diet.

The amount of bread used in our national diet is, however, considerably below its normal and proper quota. Although approximately ten billion loaves of bread are produced annually in this country, the people could advantageously consume fifteen billion loaves. Such an increase not only would be sound according to the premises of the newer or newest knowledge of nutrition, but it would have far-reaching economic effects. If, for example, every person in the United States consumed one extra slice of bread a day, it would require the production of an additional 9,000,000 barrels of flour every year, and the problem of the wheat surplus would be solved.

The nature of the American diet has been changing in recent years. Some of these changes have been beneficial, while others have been detrimental. The result is a national dietary that is superior to our fare of a generation ago, but is still below the accepted standards for adequate nutrition. It does not even approach the optimal nutrition that is such a potent factor in buoyant health.

Among the improvements in our national diet have been increases in the consumption of pure milk and other dairy products, and of fruits and vegetables, both fresh and canned. Opposed to these favorable influences has been a tremendous increase in our use of raw sugar, from about 70 pounds per capita in 1900 to 110 pounds to-day. Also opposed to the beneficial increments in some of the protective foods has been a decrease in the consumption of such valuable energy and tissue-building foods as bread, meat and potatoes.

Recent surveys by government authorities have shown that the diet of the average American is frequently deficient in calcium, iron and vitamins A, B_1 and C.[5] In order to overcome these defects, the daily diet of every normal person should

[3] W. H. Cathcart, *Am. Baking Ass. Mo. Bull.*, March, 1938.

[4] W. H. Cathcart and S. V. Luber, *Ind. and Eng. Chem.*, 31: 362, March, 1939.

[5] H. K. Stiebeling and E. F. Phipard, *Circ. No. 507*, U. S. Dept. Agr., January, 1939.

be built around such protective and energy-giving foods as milk, bread and butter, eggs, fruits, green leafy vegetables, yellow and red vegetables, potatoes and meat.

In order to improve the American diet, there is necessary a substantial increase in our national consumption of pasteurized or certified milk and other dairy products, bread and cereals, fruits and vegetables, and meat and potatoes, with less emphasis on the pure carbohydrates that are devoid of minerals, proteins and vitamins.

Good bread is the foundation of every well-balanced daily diet. Modern bread is superior to that of the past, and the bread of American bakers is now the best in the world. Baking technology is constantly striving to improve the quality of bread and bakery products, and is succeeding in making them even better. The American baking industry recognizes its responsibilities as the purveyor of a wholesome nutritious commodity that is essential to the welfare of the people. It proposes to discharge that responsibility to the best of its ability.

ARISTOTLE AND THE SCIENTIFIC METHOD

By RUFUS SUTER

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I

ONE who crosses the Charles River from Boston to Cambridge will see written across a building of the Massachusetts Institute of Technology the word: ARISTOTLE. It is an extraordinary tribute to "The Philosopher," as Thomas Aquinas called him, that his name should still appear in the stone of a school representative of the most modern of modern cultures.

The man of to-day, nevertheless, may have only a hazy notion of who Aristotle was. He was the ancient Greek, everybody remembers, who misled the astronomers for centuries by lending his authority to the idea that the stars, sun and planets travel daily (as they seem to) round the earth. He also blocked progress in physics, according to a common but historically inaccurate opinion, by championing the common-sense notion that freely falling bodies drop with a speed proportional to their weight. This much, if we do not exaggerate, is the gist of the modern man's recollection of Aristotle. But then why should his name be celebrated in the stone of the Massachusetts Institute of Technology?

If we are to resolve this curious paradox we must first recall that Aristotle was early. We are accustomed to think of the time separating us from 1610, when the greatest modern adversary of "The Philosopher," Galileo, pointed his telescope at Jupiter, as long. The time is long, in a sense, for 1610 carries us before the United States, pendulum clocks and gas lights. But the interval between 1939 and 1610 is only a few days in contrast with the lapse of time separating us from Aristotle. Even the thirteenth century, when the Polos made their amazing journeys to Cathay and Thomas Aquinas effected the final synthesis of the Peripatetic philosophy with Christian revelation, is little less than a quarter of the period to the original Peripatetic. We must travel before the beginnings of Islam, the preserver of the Aristotelian tradition when it was forgotten by the Europeans. But even this era is a thousand years later than Aristotle. In our journey we must leave the Middle

Ages behind us; pass the wild years when the Goths were sweeping down out of the north and giving the final blow to the Roman Empire; pass the day when Jesus was born in Asia Minor, whose simple maxims were to be made tremendously recondite by their incorporation in the teachings of "The Prince of them that know," as "The Philosopher" was called by Dante. We must pass some great names of Roman literature, like Cicero, who introduced Aristotelian philosophical terms into Latin, and thence into the modern languages derived from Latin: for instance, *species* from the Greek *eidos*. We must, indeed, travel before the days when Rome was an empire. At last we will come to Alexander the Great, the Macedonian who founded an empire before the glory that was Rome. Alexander in his boyhood was the pupil of Aristotle.

We have sketched this outline of some outstanding events in the past because we wished to make it vivid that Aristotle was early. To appreciate this is important if we are to comprehend why he has dominated European thought. He is to us what Confucius (if we may draw a parallel with the spiritual father of a people much discussed to-day) was to the Chinese. We have in both these men—Aristotle and Confucius—instructive examples of powerful intellects flourishing at the beginnings of civilizations, and thus able to be the fountainheads from which subsequent culture flowed.

The contrast between Aristotle and Confucius is also instructive. In the oriental sage we find the archetype of a cast of mind often characteristic of the grave, ceremonious literati of China. Frequently holders of official position, they tended, like most serious men whose concern has been with the state, to regard the deepest knowledge as insight into morals, or as having its justification in the development of character.

This moralistic view of the nature and use of knowledge is also to be found in Aristotle. The noblest man is he who understands and habitually practices the virtues. But in the thought of the Greek philosopher is a type of knowledge nobler, as it were, than the noblest. This activity has no connection with morals, the state or society. It does not derive its sanction from its capacity to develop character or citizenship. Here man, forgetting himself and his political and economic problems, broods over a reality essentially non-human. In this impractical turn to the Aristotelian mood, the west found her justification for concern with questions unrelated to the welfare of the human-race. The commentators on "The Philosopher" could investigate reality for theoretical reasons, and remain respectable citizens.

Another instructive contrast between the Greek thinker and Confucius is that the impetus which each man gave his respective civilization has led in different directions. The Confucian Classics are recensions of earlier works dealing mostly with history, ritual, political and social science and ethics. The resultant intellectual tradition has, accordingly, been humanistic. The technique of textual criticism was elaborated to a fine point, but aside from this the concern with the Confucian Classics of many generations of scholars gave birth to no consciousness of the scientific method.

Aristotle's contribution to the world, on the other hand, was his awareness of inference. This was a startlingly original appreciation, nor can one admire too strongly the mind which first became fully self-conscious here. To see clearly, for example, in the abstract, that if x is y, and z is x, then z is y, is a stroke of genius. The insight was as remarkable as that of the man who first saw, in the abstract, that $2+2=4$. The word "syllogism," in fact, given by Aristotle

to his three-step brand of inference, is the Greek equivalent of the Latin "computo"; but whereas "to compute" has come to mean "to think together" numbers or letters standing for them, "syllogism" is used exclusively for the "thinking together" of concepts such as "man" or "mortal," or letters or other symbols representing them. In Aristotle's appreciation is contained the notion of logical system.

We now have two hints of why Aristotle prepared the way for the birth and growth of science. The authority of his example made socially permissible a disinterested interest in the universe, an interest unprompted by political, social, religious or ethical bias; and under his tutelage the generations of scholars became more and more devoted to the ideal of thinking systematically.

We have, on the one hand, starting with "The Philosopher," the notion that pure science, science preoccupied with reality for its own sake, is worthy of the best type of intellect; and we have, on the other hand, also starting with "The Philosopher," the idea that genuine knowledge must be systematic. Now if we remember that for centuries, indeed until the consciousness of the scientific method fully dawned upon Europe with the advent of Galileo, the function of students was to mull over the Aristotelian writings (as, for centuries, the business of the scholars in China was to comment on the Confucian Classics) we will not be surpised that Aristotle moulded the western mind.

II

The nerve of our argument is that practise in thinking systematically was a condition of science. This is rarely noted to-day because we usually think of the scientific method in only one of its aspects: its empiricism, the importance of which was taught to us by Galileo. We tend to set it in contrast to the syllogizing, highly systematic mode of thought of our medieval ancestors. This lack of emphasis, however, is a case of the common failure to see the obvious. Before concluding we must make clear why the factor of system was as essential to science as the factor of experiment and observation.

Even the most distasteful to us of the activities of the medieval schoolmen—their indefatigable logic-chopping—had its value. It afforded experience in a heroic effort to get all knowledge into such shape that the propositions containing it could be seen to be interconnected in the way of premises and conclusions. But this form of thought (and this is what we wish to emphasize), if it is not to be hallucination, must presuppose a certain view about the form of the universe, the object which thought is assumed to fit. The world itself, in other words, must be systematic. If the syllogism: x is y, z is x, therefore z is y, is valid reasoning, and if valid reasoning is to hold true of nature, then granted that x *is* y, in the world, and that z *is* x, z must also be y in the world. For example: if all stars are suns, and if Arcturus is a star, then Arcturus is a sun, not only as a matter of valid reasoning for thought, but also as a matter of scientific fact in the universe.

Here we have shown that logically, if reasoning is to hold true of nature, nature must be conceived as fitting into the pattern of reasoning. But what is important for our purposes is not this logical point, interesting as it is, but rather a historical point. The recognition among the Peripatetics that the world is orderly came historically as a result of their concern with the systematic character of thought. Nature, except in very broad outlines, does not impress us at first with her orderliness. Instead she seems, more often than not,

fitful, arbitrary, unintelligible. She has appeared to man, in the remote past, as a kind of other-self, or other-will, opposing his own, and as irrational as he. For ages, perhaps, anthropomorphic qualities—desire to thwart, benevolence, unfairness, justice—were more naturally attributed to her than the utterly dehumanized character of abstract system. Hence it was not insight into the orderliness of external reality which produced in the worshippers of Aristotle the idea that thought must be systematic. It was, instead, the centuries of logic-chopping, inspired by "The Philosopher," which made the idea that the universe is orderly gradually become instinctive to the western mind.

It may seem ridiculous that so inescapable a pattern as the syllogism should imply anything significant about reality. It is as if we should say that since we can conclude from "No circles are squares" that therefore "No squares are circles," we know something important about order in nature. The fact is that even from such pre-syllogistic types of inference, we can conclude something important. Granted that the syllogism is utterly, obviously inescapable—as inescapable as this instance of immediate inference we have given, that the world is describable by it nonetheless signifies order, an inescapable order, if you like, but still order. It is to the credit of the Peripatetics that they educated Europe to this harmless, indubitably true, absurdly basic conception of the orderliness of nature. Here is the ground uprooted of all superstition, of all mystical ornamentation, of all religious and sociological bias, indeed of all specific and possibly disconcerting or irrelevant content whatsoever, in which the seed of empiricism, once Galileo had planted it, could take root and grow into the fully blooming scientific method. If the acutest scientists had deliberately planned the history of thought to make it finally productive of the scientific method, they could not have done better.

It is important that we grasp the immense value for science of this bare, non-committal, inescapable character of the orderliness of nature which was reflected from the syllogism. Other brands of orderliness are conceivable, and indeed have held sway over the minds of men for long periods. That they have been barren in so far as the production of scientific method is concerned, even during ages when men knew how to observe and experiment, was invariably because they included some reference to an irrelevant element which misled the minds of the investigators. For instance, men have supposed that the events on the earth were the result of events in the sky—new stars, solar and lunar eclipses, meteors and comets. Again they have imagined that the happenings and features of natural objects and living creatures in the world are symbols of various moral concepts and of ideals in the mind of God. Likewise they have made innumerable attempts to explain the phenomena of nature through ingenious but arbitrary parallelisms, such as that the number 5 is significant, and that therefore there are 5 elements, 5 planets, 5 directions, 5 virtues, 5 openings in the face, etc. All these schematisms, although they provide system in a sense, were too specific. They could, in some cases, under the creative power of extraordinarily brilliant minds, produce excellent mythology, cosmic epic poetry, rules of conduct and statutes to guarantee the permanency of the state; but they could not produce science. The scientific method required a premise in which nothing specific was asserted about the way in which the orderliness of nature expresses itself. The discovery of the way must be left to the researches of the observers and experimenters, who had

no axe—save curiosity—to grind. All that could be assumed beforehand was the fact of orderliness; and this the syllogism was able to reflect, since its form *is* order.

We could also mention here—if the consideration did not lead us too far afield—that the form reflected into nature from the syllogism is simpler and more basic than the order arising from the idea of the relation of cause and effect, at any rate in some meanings of "cause" and "effect." These concepts easily become as specific as the pre-scientific notions of order we have listed. That causality is a "push," an effort, an expenditure of energy, for example, is not unlike the notion that order is a symbol of a virtue. The difference is that the former theory has as its context a mechanistic mythology, whereas the latter has as its context a theological mythology. The former theory, although for a while it actually was helpful to science, eventually became a liability. But this consideration is beyond our present scope. What is important for us to remember is that the conception of order prolific for science was merely the conception of order, and nothing more.

In conclusion we must say a word about the relation of pure science, the disinterested curiosity to lay bare the specific embodiments of system in nature, to applied science. The Massachusetts Institute of Technology descends from Aristotle. This was our thesis. But thus far we have only been busied with showing that the possibility of pure science was conditioned in part by centuries of mulling over the systematic Aristotelian philosophy, whereas the Massachusetts Institute of Technology is a monument to applied science. The transition is easy. Once a law of nature is exposed, some practical man is certain to perceive its relevance to engineering. The practical application is naturally the final step in intellectual movement, where practical application is conceived as a large, wholesale, far-sighted, deliberate process, as it is for modern industrial science.

Thus, last is the Massachusetts Institute of Technology. Earlier is the brilliant age of dawning pure science: the period of Newton, Boyle, Galileo, Kepler. Earlier still is the preparatory era: the age of scholasticism and of its Peripatetic precursors in Islam and the late Roman Empire. Then, first is Aristotle.

BOOKS ON SCIENCE FOR LAYMEN

GONE WITH WIND AND WATER[1]

We have here a thorough scrutiny of the problem of soil erosion on all continents. The authors, both British, are competent professional students of soil. They are also, like large numbers of their scientific colleagues in the British Isles, keenly aware of the social implications and responsibilities of science. So far as their political attitude comes to light, it is unsentimental. Yet nothing more deeply disturbing than this book, even among American writings on soil erosion, has appeared.

The factual account of soil destruction, continent by continent, is reenforced by a picture of its effect on the lives of human beings. No doubt remains regarding the operation of soil erosion as a major factor in human history. And the reader, after learning of the situation in Africa, Australia, Asia and the Americas, has little trouble in agreeing that man is in for a race against time to preserve one of the foundations of his social structure. Correctly, the world-wide mischief is attributed to the exploitation which has accompanied the flowering of western Europe, itself largely immune to the worse types of soil erosion. Incidentally, it is the reviewer's opinion that one can not understand the present plight of Europe itself without considering it a vast metropolis which for three hundred years has utilized the rest of the world as hinterland.

Less accurate, perhaps, is the authors' statement that the mischief is due to the spread of a system of land use which worked well enough under European conditions, but which could not work elsewhere. In effect, the authors elsewhere qualify this statement, yet it is a clue to the least satisfactory phase of their report. For they quite ignore the contrast between Teutonic patterns of land use and management in this country and those of British origin. The former have generally resulted in a minimum of destruction; the latter have been highly exploitive and dangerous. One of the most practical approaches to our problem here lies in a study of the many communities, largely German, Dutch and Scandinavian, in which a well-balanced relation has been maintained for long periods of time. The picture is black enough, God knows, but not wholly so.

Students of population problems will search in vain for suggestions of improvement through birth-control. While admitting that erosion arises from population pressure, the authors insist that hope lies in still more acute pressure of this sort, enforcing respect for land. Japan and Java are cited as examples. The reviewer must beg to remain not wholly convinced, quite apart from the question of wars and other social conflicts which attend readjustments through sheer human pressure.

Of particular interest is the discussion of political and social consequences with which Mr. Jacks concludes the volume. For Africa, a humane type of feudalism, with the blacks anchored to the land under white supervision, is suggested. Much is made, and rightly, of the resemblances and contrasts between Russia and the United States. The authors are convinced of the growing need for collectivism everywhere. On the whole, they seem inclined to prefer the rather blundering and deliberate democratic approach, which is getting under way here, to the more violent and Utopian pattern in Soviet Russia.

The technological improvements which have been developed, largely in this country, are discussed intelligently and in

[1] *Vanishing Lands.* By R. O. Whyte and G. V. Jacks. Illustrated. xvi+332 pp. $4.00. Doubleday, Doran and Company.

considerable detail. The role of education, however, is passed, except in connection with the proposed new feudalism for Africa, and one misses the name of Hugh Bennett, apostle of conservation, in the index. After all, the American way of living is remarkably flexible in meeting emergencies, once the people are made to understand that emergency exists. Public information is a most vital link in erosion control.

There is a growing group, both among extreme radicals and their mortal enemies, the industrialists, which might be called Neo-scientist. Tacitly it is assumed to speak for all scientists. This group pins faith on the multiplication of inventions and devices and builds on the Marxian idea that rural life is a form of folly and urban comfort the only wisdom. In contrast, this book starts squarely on the assumption that soil is the basis of civilized life, and that human ecology, as a source of perspective, is one of the most urgent needs of mankind. By inference, conservation is less a technique than an attitude.

The struggle between those who would live with the soil and those who would live off of it is perennial in human history, nor is it by any means nearly at an end. Meanwhile we are obliged to agree with the authors of this important book that the present emphasis on nationalism is not wholly a curse, for it is everywhere rubbing the soiled noses of men into the cleanly soil.

PAUL B. SEARS

CLASSICS OF GEOLOGY[1]

GEOLOGISTS frequently temper their confessions of ignorance with the statement that theirs is a young science. If seekers for information reply by mentioning Avicenna (980–1037), Avempace (d. 1138) and Leonardo (1452–1519), that argument seems to crumble. How can a science be young when its roots go back almost a thousand years?

This book answers that question: the "roots" were no more than sporadic flashes which led to nothing. No one pursued Avicenna's outline of mountain building; Avempace touched upon the earth only incidentally; Leonardo's notebooks were not published until long after his death. The fact that he had no immediate influence is shown by the lack of any sixteenth century writer who applied Leonardo's ideas concerning fossils, the salinity of the sea and sedimentation. Indeed, the contributions of sixteenth and seventeenth century writers combined fill only 40 pages in this volume, while those of eighteenth-century workers fill 117 pages. The remainder of the book (524 pages) traces the growth and specialization of earth science during the nineteenth century.

This means that geology, as geology, is barely 140 years old. In spite of this, some of its most modern phases date back to early years. Thus Sir James Hall studied molten rock in the laboratory before 1805 and made marble in 1811 or 1812. Nicol described his well-known prism for the microscope in 1829, and James Hall of Albany advanced the concept of geosynclines in 1857. Even the planetesimal hypothesis, which has barely begun to displace Laplaceism in popular thought, was clearly stated by Chamberlin and Moulton almost 35 years ago.

These are a few of the high lights in a book which, in itself, presents the high lights of published geology during four centuries. A total of 126 authors are presented—some through papers which have been forgotten, even though their substance appears in almost every geologic text-book. Outstanding examples are Babbage's account of the temple of Jupiter Serapis and G. P. Marsh's discussion of the relationship between deforestation and floods. Even more significant is Agassiz's summary of evidence for a glacial age, translated from a book published while he was professor at Neuchâtel.

In short, this "Source Book" presents

[1] *A Source Book in Geology.* By Kirtley F. Mather and Shirley L. Mason. xxii + 702 pp. $5.00. McGraw-Hill Book Company.

a detailed, as well as a well-rounded, survey of a relatively new science that already has forgotten much of its history. By bringing important yet relatively obscure papers to light, it also provides materials for histories of geology that are yet to be written.

C. L. F.

THE ORIGIN OF LIFE[1]

THE book, which is devoted to a description of studies of artificial non-living systems showing a faint resemblance to accepted living organisms, is divided into four sections, the opening one of which is called "The First Approach: Vital Growth and Crystallization." The forces involved in crystallization have long interested both scientists and laymen and are invariably invoked whenever life processes are under discussion; hence, they may rightfully be included in the subject-matter of a book on the origin of life. The author compares the growth of crystals with that of organisms and concludes that the two have common features. Unfortunately, emphasis has been placed on a description of the many forms which may result from the forces of crystallization, and but little is said concerning the nature of the forces and their possible rôle in life processes.

The second section, titled, "The Second Approach: Life, Carbon's Outstanding Property," is concerned with the development of chemistry, some elementary chemical facts and some of the recent chemical work on viruses. There is included a two-page discussion of the origin of life on the earth and a ten-page survey of Oparin's book entitled "The Origin of Life." The ideas expressed by the author and by Oparin are very similar and appear to differ in only one fundamental point. It is stated that "the essential feature of Oparin's hypothesis is that structural units with a remote resemblance to living organisms were *first* formed from the organic matter of the early ocean and that subsequently enzymes formed in them . . .," whereas the author expresses the view "that the life-producing enzymes were the first to appear, through the action of electric discharges, without any structure around them—as self-regenerative enzymes. Later only, a structure was built up around them. . . ." The latter are assumed to have properties somewhat similar to those ascribed to viruses, and the recent work on the isolation of certain viruses in the form of high molecular weight nucleoproteins is cited as evidence for the probability of such a sequence of events. In view of the important rôle played by viruses in the author's theory, it would have been well to have included a short exposition of the view-point held by many that viruses arose not abiogenetically but from living organisms by some degradatory process. Furthermore, the emphasis which is placed upon the carbon compounds could have been concentrated on the protein molecule with greater propriety.

In the third section entitled, "The Third Approach: The Importance of Salt and Water for Life and Growth," the author shows how the blood of animals may have been developed in early evolution from the ocean, which he refers to as the cradle of life. The last section, "The Fourth Approach: The Animal a Machine," serves to describe various artificial systems which simulate in one way or another certain activities of living organisms. As a whole the subject-matter of the book is not well integrated and there is much that is not relevant. It is unfortunate that there are some misstatements which will probably irritate the scientist and mislead the layman. The book is not so much a discussion of life's beginning on earth as it is a record of the author's extensive interests and experience, both as an experimenter and as a student of the literature, and as such it may be recommended to the interested reader.

W. M. STANLEY

[1] *Life's Beginning on the Earth.* By R. Beutner. Illustrated. x + 222 pp. $3.00. Williams and Wilkins Company.

DR. CUSHING AND A YOUNG PATIENT—1928

THE PROGRESS OF SCIENCE

HARVEY CUSHING: AN APPRECIATION

HARVEY CUSHING, renowned physician and neurological surgeon, came as the fourth in line of a New England family of doctors who had settled in the Western Reserve early in the last century. Grandson of Erastus Cushing, M.D. (1802–1893), and son of Henry K. Cushing, M.D. (1827–1910), Harvey Cushing was born in Cleveland, Ohio, on April 8, 1869; he received his B.A. degree from Yale College in 1891 and his M.D. degree from Harvard in 1895. After serving as surgical house pupil at the Massachusetts General Hospital under J. W. Elliot during 1895–1896, he had four additional years of surgical training under William S. Halsted, the professor of surgery at Johns Hopkins University. He then spent a year in Europe, during which time he studied under the physiologist Hugo Kronecker at Berne and later under Charles Sherrington in Liverpool; in 1901 he returned to the United States to take up a surgical career at Johns Hopkins. Called to Harvard in 1912, he assumed his duties in Boston as Moseley professor of surgery and surgeon-in-chief of the Peter Bent Brigham Hospital in 1913. Shortly after the beginning of the World War, he organized a surgical unit which he later took to France (March 18, 1916), where he stayed with one brief interruption until April, 1919. After his retirement from the Harvard chair in 1932, he came again to Yale to occupy a new Sterling professorship of neurology created for him in the School of Medicine; in 1937, he became professor emeritus and received the title of director of studies in the history of medicine.

Harvey Cushing was widely known in three distinct capacities—as a great physician, as the founder of a school of neurosurgery and as a humanist of unusual literary attainment. When his seventieth birthday was celebrated in April, 1939, the *New England Journal of Medicine* wrote in an editorial: "The world at large will also be thinking of this great figure in American medicine, perhaps the foremost physician produced by the United States."

Dr. Cushing prided himself upon being, first of all, a physician—a "good doctor." For him surgery was merely a form of therapy, and the primary responsibility of every man who entered the surgical field was to make himself at the outset thoroughly competent in the science as well as in the art of general medicine. In this he took inspiration from the example of his distinguished teacher, William Osler, whose biography he ultimately prepared. In clinical medicine, Cushing made many pioneer contributions. He was one of the earliest in this country to appreciate the importance of the x-ray, his first scientific paper communicated to the Johns Hopkins Medical Society on May 3, 1897, being devoted to this subject. He was also the first to introduce the use of blood-pressure determinations in the United States (1901), and was an early advocate of the importance of studying the basal metabolic rate. Late in his clinical career (1932), he described a new clinical entity, "pituitary basophilism," which is now known eponymically as "Cushing's disease." In addition to making these individual advances, he was a life-long student of the diseases of the ductless glands, particularly those arising from disturbances of the pituitary body. His monograph on the pituitary gland, published in 1912, has remained one of the classics of clinical medicine. As a physician, he was a quick and penetrating observer, always preferring the evidence of the five senses to that obtained from instruments of pre-

cision; and his unfailing insistence upon the completeness of the case record earned him the epithet of "the physician of the written word." His case histories, even during his early days as interne at the Massachusetts General Hospital, were models of completeness, and where the written word failed in clarity it was supplemented by a skilful free-hand sketch, of which art Cushing was also an accomplished master. On his seventieth birthday it was said of him that his soul, as well as his technique of life, was essentially that of an artist.

Dr. Cushing was more widely known in the world at large as the founder of a special field of surgery. It is true that he created a school of neurological surgeons, and from the ends of the earth he attracted students who are now carrying on, in almost every country of the world, something of the high tradition which he had established. But he did much more than establish a school of neurosurgery, for he also perpetuated and extended into the broader field of general surgery the traditions established by Halsted: slow and painstaking dissection, gentle handling of tissues and the universal use of silk for closing wounds—all these things have become the creed and ritual of the Halsted-Cushing school which, by their pupils, especially those of Cushing, have been carried into every phase of surgical endeavor. In the field of his special interest, the surgery of the nervous system, to which he devoted time and attention over a period of more than thirty years, Cushing introduced innumerable technical improvements. These advances, culminating in the introduction of the electrosurgical knife in 1927, made it possible for the surgeon to enter the human brain with as much confidence of success as the abdominal surgeon who enters the abdomen to remove an appendix. The majority of these advances in cerebral surgery are, by common consent, due to the unremitting labor of Harvey Cushing alone; indeed, the procedures which he has introduced have been adopted wherever neurosurgery is practised. His scientific contributions in this special field include important studies of the physiology of the pituitary, the classification and details of the life history of every form of cerebral tumor, and important observations upon the physiology of the human brain, the most notable of these being the description of the sensory concomitants experienced by conscious patients during stimulation of the postcentral convolutions of the brain. Cushing also did much toward clarifying various clinical entities caused by specific lesions of the nervous system, and he is credited with having crystallized many clinical syndromes of neurology.

Finally, Cushing held high the traditions of the literary physician. From William Osler he derived an abiding interest in the more cultural phases of medicine, medical history, medical art and in the origins of our medical institutions. The art of writing never came easily to him, and his early papers can scarcely be looked upon as models of lucid exposition or fluent prose. He "slaved" day and night over the shortest paper, and everything he published went through countless drafts; and by dint of this constant effort he acquired a literary style that was vivid, characteristic and distinguished. His "Life of Sir William Osler" (1925) earned him the Pulitzer Prize for biography and some of his shorter literary papers, such as his appreciation of Welch on his eightieth birthday, and his Lister centenary address entitled "Emancipators" (1927), stand among the finest pieces of prose in our literature. Throughout his career as a physician, Cushing retained a deep admiration for one of the fathers of the art, Andreas Vesalius, founder of modern anatomy. For forty years he collected his works and his most recent literary endeavor was the compilation of an exhaustive bibliography of the Vesalian writings. His last published work, how-

ever, was a warm-hearted and characteristically generous appreciation of his colleagues in the surgical art, Charles and William Mayo (*Science*, September 8).

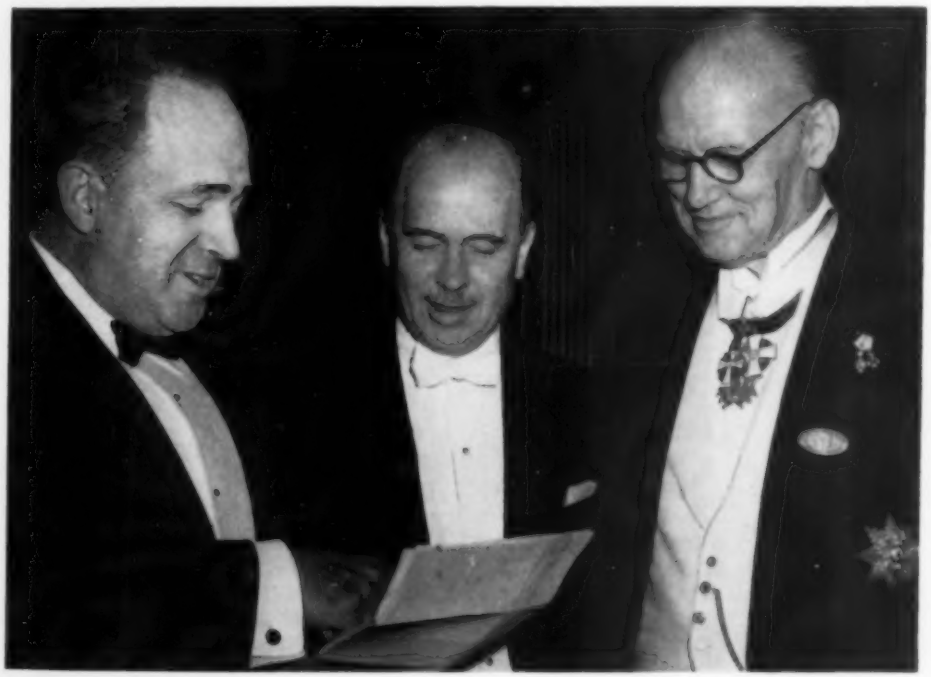
Dr. Cushing's library of medical and scientific classics, which has been bequeathed to the Yale University School of Medicine, is one of the finest ever brought together by a private person.

J. F. FULTON, M.D.
YALE UNIVERSITY SCHOOL OF MEDICINE

SEVENTH ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

DESPITE disturbed conditions abroad and the actual outbreak of war among certain of the adhering nations, the Seventh Assembly of the International Union of Geodesy and Geophysics convened in Washington from September 4 to 15, under the presidency of Dr. D. la Cour of Copenhagen, Denmark, with representatives of over 26 nations and a total registration of 537 delegates and guests, including 116 from foreign countries.

At an early meeting of the executive committee, and after consultation with the State Department, it was decided that, with the large number of delegates already present and the great amount of material to be presented, the scientific aspects of the Seventh Assembly could proceed substantially according to the original schedule. It was voted, however, in view of the fact that many persons could not be present and certain countries, therefore, were not adequately represented, that matters of administra-



DR. D. LA COUR, OF COPENHAGEN, PRESIDENT OF THE UNION (*RIGHT*)
Center: HUGH WILSON WHO READ THE ADDRESS OF WELCOME FOR SECRETARY HULL. *Left:* DR. CLOYD H. MARVIN, PRESIDENT OF GEORGE WASHINGTON UNIVERSITY.

ATTENDING THE MEETING OF THE INTERNATIONAL UNION OF GEODESY

Left: CAPTAIN C. L. GARNER, OF THE UNITED STATES COAST AND GEODETIC SURVEY, CHAIRMAN OF THE COMMITTEE FOR ENTERTAINMENT. *Right:* DR. ROSS G. HARRISON, OF YALE UNIVERSITY, REPRESENTING THE NATIONAL RESEARCH COUNCIL.

tion, finance and elections should be omitted and the entire attention given to the discussion of scientific matters.

In opening the formal program, the introductory address was given by Dr. Richard M. Field, president of the American Geophysical Union, which was the official host for the Seventh Assembly of the International Union. In his address, Dr. Field said in part:

. . . The program of this Seventh Assembly now gathered in Washington concerns itself chiefly with those fundamental aspects of the sciences of the earth dealing with the problems of the earth's crust, its oceans and its atmosphere that can not be solved except by the cooperation of many nations to whom are entrusted various territories of our globe. It is only through the acquisition of scientific information covering the entire surface of the globe that many of the basic problems underlying the dynamics of the earth and of its atmosphere can be solved.

Following the opening remarks of President Field, an address of welcome by the Honorable Cordell Hull, Secretary of State, was read by the Honorable Hugh R. Wilson, which in part was as follows:

Your studies in the fields of seismology, volcanology, meteorology, terrestrial magnetism and electricity, oceanography and hydrology are of daily interest and importance not only to our governmental agencies responsible for official activities in those spheres but also to innumerable private organizations and individuals whose economic existence is dependent upon your efforts. Millions of persons throughout the world owe in a large measure their comfort and livelihood to your notable contributions to the improvement of scientific aids to transportation by water, land and air, of building methods designed to minimize danger from earthquakes, of agricultural practices utilizing knowledge of surface and subterranean water supplies, of geophysical methods of prospecting and of the study of underground formations.

The response to the Secretary of State was made by Professor S. Chapman, chairman of the British National Committee.

A welcome on behalf of science was presented by Dr. Frank B. Jewett, president of the National Academy of Sciences. Significant among Dr. Jewett's remarks are the following:

> Whatever the future has in store for the world and its inhabitants, it is, I think, safe to say that every increment to our store of real knowledge is potentially an increment added to a better way of life. It may be a long way off, but the possibility of its attainment justifies our continuing the quest. The field you represent is one of the most important in the whole domain because it is concerned with the very foundation on which all else rests.
>
> On behalf therefore not only of the National Academy of Sciences and of the National Research Council but of American science in its entirety I wish you an outstandingly successful conference.

The general meetings of the associations were marked by the holding of many joint sessions at which important symposia dealing with fundamental problems of the earth and its atmosphere were presented. The Association of Geodesy, for example, joined with the associations of Seismology, Meteorology, Physical Oceanography and Scientific Hydrology to discuss such basic problems as were presented in the report of the Commission on Continents and Ocean Basins. The Association of Meteorology was joined with that of Terrestrial Magnetism and Electricity on September 8, at which the president of the Association of Meteorology, Professor S. Chapman, delivered the presidential address on "Atmospheric Tides and Associated Phenomena." All the meetings of the Union emphasized the interpenetration of the work of the many associations, as specific

DELEGATES TO THE GEODESY UNION MEETING

Left to right: DR. WILLIAM BOWIE, OF WASHINGTON, ACTING SECRETARY-GENERAL OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS; DR. R. M. STEWART, DIRECTOR OF THE DOMINION OBSERVATORY, OTTAWA, CANADA, AND DR. GUSTAF SLETTENMARK, OF STOCKHOLM, SWEDEN, VICE-PRESIDENT OF THE ASSOCIATION OF SCIENTIFIC HYDROLOGY.

problems of the earth sciences invariably cross the fields of many workers in the conventionally departmentalized lines.

The Commission on Continents and Ocean Basins attracted large numbers to its sessions, occupying three half-days of the Union's program. A special session on tectonophysics attracted attention to a new and growing field of importance to all investigators in structural geology. The uplift of land in Fennoscandia was presented by W. Heiskanen, of Finland, and the derivations of the viscosity of the substrata were discussed by F. Vening Meinesz. The problem of the creep of rocks was presented from the experimental point of view by D. Griggs, while the theoretical side of the same problem was outlined by R. W. Goransen. The consideration of the flow of substrata in problems of earth deformation by B. Gutenberg concluded this session.

There were two distinguished lectures of general public interest. The first, on "Round the World with Geodesy," was prepared by Brigadier H. St. John L. Winterbotham, General Secretary of the Union, but was read by Dr. William Bowie, ex-president of the International Union and General Secretary, *pro tem.* The second, on "From the Mexican Gulf to the Arctic Sea—the Gulf Stream and Its Significance," was delivered by Dr. Helland-Hansen, of the Geophysical Institute at Bergen, Norway.

A special convocation was held at George Washington University on September 11, at which honorary degrees of doctor of science were conferred upon Dr. D. la Cour of Copenhagen, president of the International Union, and *in absentia* upon Brigadier H. St. John L. Winterbotham.

Excursions were conducted to the International Latitude Station at Gaithersburg, Maryland; the magnetic observatory of the U. S. Coast and Geodetic Survey at Cheltenham, Maryland; and to the Carnegie Institution's Geophysical Laboratory, and to the Department of Terrestrial Magnetism.

An unusual feature of the assembly was the excellent exhibit of geophysical instruments, charts and models representing progress in geophysical exploration, which was arranged under the direction of Captain Paul Whitney.

HARLAN T. STETSON
MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

THIRD INTERNATIONAL CONGRESS FOR MICROBIOLOGY

THE Third International Congress for Microbiology met in September in New York City, under the presidency of Dr. Thomas M. Rivers, director of the Hospital of the Rockefeller Institute. In spite of the outbreak of hostilities abroad, which kept at home about one half of the 400 foreign scientists who had made their arrangements to come to New York, the meeting was acclaimed by those who were able to attend as notably successful and stimulating. All agreed that it was a worthy successor to the first and second congresses, held in 1930 at Paris and in 1936 at London, which like the present congress, were organized under the auspices of the International Association of Microbiologists. Largely responsible for the splendid spirit of the occasion was the determination of the foreign group not to let the anxieties of war interfere with the business of the congress.

A plan of international scope was formulated with the object of preventing the recurrence of another world-wide outbreak of influenza, which attacked no less than one fifth of mankind during the last great war. In the light of knowledge acquired during recent years on this worst of pestilences, it may not be too much to hope that another epidemic of influenza can be checked before it spreads beyond the country of its origin. This will necessitate the closest cooperation

DR. THOMAS M. RIVERS

between workers in all countries, with the immediate distribution of the strain of virus responsible for the outbreak. With this strain available, public health authorities will be in a position to institute preventive measures, such as vaccination, in which considerable progress was reported. Of the many achievements of the Congress, the inauguration of this plan illustrates, perhaps better than any other, the importance for human welfare of letting nothing stop scientific investigation, and contrasts the international activities of the scientist with the nationalistic objectives of the politician.

The official registration of the Congress was 1,624. Of this number, 250 were from abroad, representing 40 countries. Over 800 were present to hear the welcoming addresses of Dr. Rivers and of the Honorable Fiorello H. La Guardia, Mayor of the City of New York. Sir John C. G. Ledingham, director of the Lister Institute, London, who was president of the Second International Congress for Microbiology, responded on behalf of the official delegates from abroad. Dr. Lewis R. Jones, professor emeritus of the University of Wisconsin, and Dr. John L. Rice, Commissioner of Health

for New York, also spoke. On Monday evening the Rockefeller Institute entertained 850 at a delightful reception. The final official social gathering was the banquet on Friday night, which was attended by 500. The addresses emphasized very well the international character of the occasion, for the speakers were representatives of 10 countries.

The scientific program was divided into nine sections, which ran concurrently each morning for five days. Several of the sections were so large that two divisions had to be held simultaneously. In all, 625 papers were scheduled and approximately 475 were read, most of the remainder being cancelled because of the outbreak of war in Europe. Three afternoons were also devoted to 40-minute lectures of a general nature by men distinguished in their respective fields. They were presented by Dr. B. O. Dodge (New York), Dr. Paul Fildes (London; read for him by Sir John C. G. Ledingham), Professor J. J. van Loghem (Holland), Professor John R. Marrack (London), Dr. N. H. Swellengrebel (Amsterdam), Dr. W. M. Stanley (Princeton) and Professor Dr. Arne Tiselius (Upsala). A colored motion picture, depicting the life-cycle of the woodtick, *Dermacentor andersoni,* which was made at the Rocky Mountain Spotted Fever Laboratory at Hamilton, Montana, by members of the United States Public Health Service, was shown on the final afternoon of the sessions.

It is not possible to deal here in detail with any of the many papers given at the Congress. It is feasible, however, to discuss the general trend of the scientific work presented. This can be accomplished best by considering each of the nine sections separately.

General Biology: Variation and Taxonomy (4 sessions, 51 papers scheduled). The discussion of the as yet unclassified, filterable microorganisms, including those of the pleuropneumonia group, was one of the most interesting of the Congress. The study of these recently discovered organisms, which seem to fall between the bacteria and the filterable viruses, is rapidly yielding a new insight into bacterial enzyme-systems and their significance in parasitism. The complications which variation introduces into the classification of bacteria and fungi were also considered.

General Biology: Microbiological Chemistry and Physiology (5 sessions, 64 papers scheduled). The entrance of the chemist into the field of bacteriology has led already to the accumulation of a vast amount of information on the metabolism of microorganisms, and the acceleration of activity in this borderland continues at a bewildering pace. Bacteria lend themselves particularly well for investigations of the essential growth substances required by cells, and the knowledge of these bacterial "vitamins" is already of great importance in other fields, such as that of animal nutrition. So, too, do bacteria provide a fine material for the investigation of enzymes.

Viruses and Viral Diseases (9 sessions, 114 papers scheduled). Special interest was shown in the sessions dealing with the nature and characteristics of viruses, as revealed by the newer physical and chemical methods for analyzing their properties, with the relation of viruses to tumor formation, and with epidemiological studies of influenza. Papers were also read on various plant and animal viral diseases, including the encephalitides, poliomyelitis, rabies, yellow fever and vaccinia.

Rickettsiae and Rickettsial Diseases (2 sections, 21 papers scheduled). All phases of recent work in this active field were discussed, with particular interest manifested in the epidemiology, immunology and chemotherapy of rickettsial diseases.

Protozoology and Parasitology (5 sessions, 60 papers scheduled). The mechanisms of immunity and resistance to protozoan and helminth infections occu-

pied the attention of two of the sessions, while the remainder of the program was devoted to a consideration of the parasites themselves, particularly to their life-cycles.

Fungi and Fungous Diseases (7 sessions, 96 papers scheduled). The fact that plants suffer from a wide variety of bacterial, fungous and viral diseases, much as animals do, may come as something of a surprise to many people. Nevertheless, such diseases are quite as important, perhaps more important in their total effect, than the more familiar infectious maladies of men and animals. Indeed, much that is known of the relationship of infectious agent to host has been gained from the study of plant infections. The sessions were devoted to a broad consideration of all aspects of the host-parasite relationship, from a survey of the growth substances required by the microorganisms to a consideration of the mechanisms of host resistance. The subjects of sex, variation and genetics of the fungi were taken up at a special session.

Medical and Veterinary Bacteriology (7 sessions, 85 papers scheduled). The study of animal diseases in their natural hosts, rather than the study of human diseases transferred to alien animal hosts, is the approach to the principles of infection and resistance which is so rapidly disclosing information of the greatest importance in both the medical and veterinary fields—hence the joint section. Chemotherapy, naturally, received much attention. The ability to cure infection with some of the new chemicals now available is little short of miraculous. Tuberculosis, syphilis and the other spirochaetoses, diphtheria, plague, enteric infections, wound infections and streptococcal infections came in for consideration.

Agricultural and Industrial Microbiology (5 sessions, 68 papers scheduled). Various sessions were devoted to the microbiology of soil, to dairy bacteriology, to the bacteriology of water and sewage, to foodstuffs and food-spoilage and to fermentation, the activity of bacteria and fungi which underlies much of the great chemical industry.

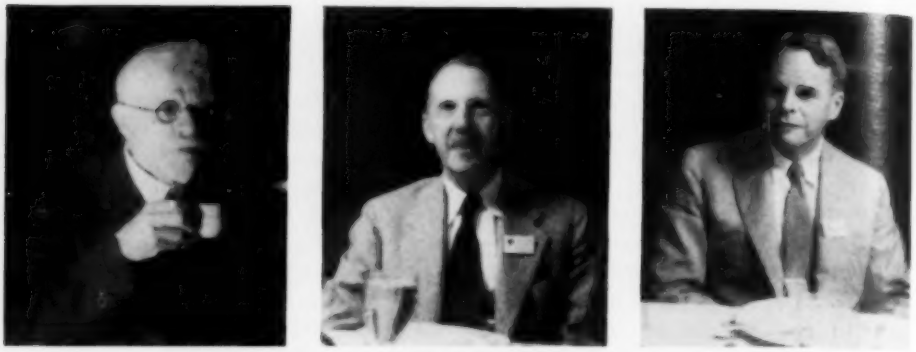
Immunology (5 sessions, 66 papers scheduled). Outstanding in the field of immunology has been the recognition of the complex factors involved in tissue immunity. The volume of work on the complex chemical substances making up the multiple antigenic structure of microorganisms has been striking, as have been the stimulating researches on the mechanism of immune reactions.

The Congress closed formally with a business session on September 9, at which committee reports were accepted, including that of the nomenclature committee. This group straightened out some of the conflicts which have so plagued bacteriologists. The Fourth International Congress for Microbiology was scheduled for Copenhagen in 1942. The president of the International Association of Microbiologists which conducts the congresses is to be elected within the next few months by the principal microbiological organization of Denmark.

GEORGE PACKER BERRY, M.D.,
Professor of Bacteriology
UNIVERSITY OF ROCHESTER

THE MEETING OF THE AMERICAN CHEMICAL SOCIETY IN BOSTON

THE centenary celebration of Charles Goodyear's discovery of the vulcanization of rubber was a feature of the ninety-eighth meeting of the American Chemical Society, which took place in Boston from September 11 to 15. The program of the general meeting of the society was devoted to Goodyear's discovery and its applications; rubber was also the subject for discussion at the subscription dinner, which was attended by 965 members and which was addressed by Drs. P. W. Litchfield, Karl T. Compton and J. B. Conant. The centenary was also marked by: an exhibit, in which the rubber industry participated, arranged by the division of



DISTINGUISHED CHEMISTS AT DIRECTORS' DINNER

DR. CHARLES A. KRAUS, PRESIDENT OF THE SOCIETY AND DIRECTOR OF CHEMICAL RESEARCH, BROWN UNIVERSITY; DR. SAMUEL COLVILLE LIND, PRESIDENT-ELECT OF THE SOCIETY AND DEAN OF THE INSTITUTE OF TECHNOLOGY, UNIVERSITY OF MINNESOTA, AND DR. HOBART H. WILLARD, PROFESSOR OF CHEMISTRY AT THE UNIVERSITY OF MICHIGAN.

rubber chemistry; the announcement of the Charles Goodyear Lectureship to stimulate rubber research and to recognize outstanding contributions in the field; and the action of the Board of Directors to sponsor the nomination of Goodyear for election to the Hall of Fame. The twenty-five papers presented

AT THE SPEAKERS' TABLE

P. W. LITCHFIELD, PRESIDENT OF THE GOODYEAR TIRE AND RUBBER COMPANY; J. M. BIERER, TOASTMASTER AND CHAIRMAN OF THE DINNER; DR. JAMES B. CONANT, PRESIDENT OF HARVARD UNIVERSITY, AND DR. KARL T. COMPTON, PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

in the division of rubber chemistry were of interest in view of the centenary; sixteen were included in a symposium on the vulcanization of rubber, during which the use of agents other than sulfur in vulcanizing were particularly examined. The possibility of producing "artificial" rubber economically was also discussed at the division meeting; it was suggested that butanes and pentanes obtained from petroleum may be converted into butadiene and isoprene, the basis of "artificial" rubber.

Outside the field of rubber research, one of the most widely discussed papers was that by Dr. George Calingaert, who announced the discovery of a new type of chemical reaction. By adding certain specified catalyzing agents, he found it possible to weaken the chemical bonds in the molecules of certain chemical compounds, and thus to cause reactions between compounds which had hitherto been considered inert toward each other. Parts of molecules thus become redistributed in harmony with the laws of probability rather than in accordance with chemical laws. Such "redistribution reactions," as they have been named, do not involve changes in heat, appearance or physical state, and only when the substances of a mixture are separated is it possible to determine whether new compounds have been formed. It was suggested that this newly discovered type of chemical reaction may be responsible for such hitherto unexplained processes as the aging of liquors. A wide range of applications in industry is foreseen; the elimination of intermediate steps in certain processes is made possible, and waste is avoided because the reaction involves every part of the compounds present.

The 568 papers presented at the meeting were divided among the eighteen technical divisions of the society. Symposia, often including representatives from more than one division, were presented on a large variety of subjects, both theoretical and practical. One symposium was devoted to training and opportunities for women in chemistry.

The symposium on industrial wastes discussed legislation proposed to end pollution caused by industrial plants; the creation of a federal board to study the question and draw up uniform legislation was urged by speakers. The problems in individual industries were considered, and it was emphasized that waste treatment should be considered in planning new industrial plants.

The papers presented at the symposium on vitamins and nutrition included announcements of several discoveries. A

DRS. WHITMORE AND EGLOFF

DR. FRANK C. WHITMORE, PAST PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY AND DEAN OF THE SCHOOL OF CHEMISTRY AND PHYSICS, PENNSYLVANIA STATE COLLEGE, AND DR. GUSTAV EGLOFF, DIRECTOR OF RESEARCH, UNIVERSAL OIL PRODUCTS COMPANY.

method of separating vitamins A_1 and A_2 by the use of hydrochloric acid was reported. Xanthophyll, the chemical causing the color in "yellow-legged" chickens, was found to be a necessary ingredient in chicken feed, and was therefore stated to be a vitamin. The discovery of a new vitamin, B_x, preventing the graying of hair, was announced.

The numerous other papers presented at the meeting included announcements of such widely varying discoveries as a process of canning blue crab meat without discoloration, the successful appli-

cation of spectroscopy in determining minute quantities of metals in animal tissues, and a powerful but non-deleterious new germicide prepared from whale oil.

Registration at the meeting totalled 3,924; forty-seven states and twenty foreign countries were represented. Excursions were made to nearby points of interest, and programs were arranged by the faculties of neighboring educational institutions. Reports were submitted by committees appointed to prepare a pamphlet guiding prospective chemistry students, to accredit institutions teaching chemistry and to study problems of small local sections. Formal sessions of the society were concluded on September 15; it is planned to hold the next meeting of the society at Cincinnati from April 8 to 12, 1940.

B. I. G.

CASUALTIES IN SCIENCE

It is natural to think first of the casualties of war as consisting of the men killed and injured. As tragic as such losses are, their consequences are probably no more serious for the future of humanity and civilization than are the destructive effects of war on the finer things of the mind. Already science is suffering serious wounds.

Last year in September a congress on malaria in Holland was disrupted by the international tension over Czecho-Slovakia. The meeting of the British Association for the Advancement of Science, which was to be held in Dundee, Scotland, during the first week of last September, was interrupted after it started, one of the results being that Dr. Isaiah Bowman was unable to deliver his address as the first exchange lecturer under the arrangement between the British Association and the American Association. The programs of the recent scientific congresses reported in this issue of THE SCIENTIFIC MONTHLY were impaired by the fear of war that deterred many foreign scientists from attending them. Future scheduled scientific congresses will be postponed or abandoned if the war continues.

Scientific publications likewise are already suffering. It has been announced that *Science Progress*, now in its thirty-fourth volume, will be discontinued, at least for the duration of the war. In fact, *Nature* has stated that British scientists will resolutely devote their energies to winning the struggle. In neutral Holland Dr. Frans Verdoorn is finding it difficult, if not impossible, to continue the publication of the distinguished *Chronica Botanica*. International weather services, on which safe transoceanic airplane flights depend, are seriously impaired.

Scientific expeditions will generally be abandoned or suspended. Already it has been announced that the expedition to the South-Central Pacific Islands will not be undertaken, and one of the U. S. Government vessels that was to accompany Admiral Byrd's projected explorations in Antarctica has been withdrawn. It would be worth while for some one to keep a record of these casualties of science.

Naturally the countries at war are suffering the most serious consequences to their cultural life. The attendance at all their universities will be reduced, and inevitably the historic atmosphere of these famous institutions will be poisoned by the war. It is reported that twenty-two German and Austrian universities will be closed, leaving only those at Berlin, Munich, Jena and Vienna in operation. No glories of war can illuminate the darkness produced by the closing of these many famous centers of culture.

F. R. M.

LUNAR ECLIPSE ON OCTOBER 27–28

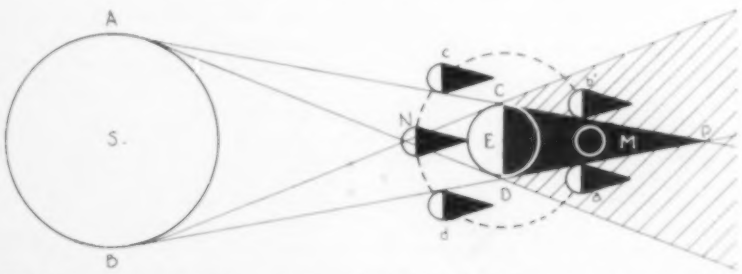
On October 27, at six minutes before midnight, Eastern Standard Time, the moon will begin to pass into the earth's shadow. At 1:36 A.M. the eclipse will be at its maximum, when 99.2 per cent. of its disk will be darkened. The eclipse lacks a little of being total because the moon does not pass centrally through the earth's shadow but across its southern border, as is shown in the diagram. At 3:18 A.M. the moon will emerge completely from partial eclipse.

Since the shadow of the earth is opposite to the sun and the eclipse occurs during the midnight hours, the moon will be near the meridian and most favorably situated for observation. There is a partial shadow around the region from which the sun's light is entirely cut off, also shown in the diagram. Consequently, the moon will be gradually darkened for an hour before the moon begins to enter the complete shadow.

It is slightly erroneous to speak of the shadow of the earth as being complete, because the thin layer of the earth's atmosphere acts somewhat like a converging lens and bends some of the rays from the sun into the shadow cone. These rays are mostly the orange and red because the atmosphere absorbs the blue end of the spectrum and partially transmits the red, a fact that is illustrated by the deepening color of the sun as it sets. The moon is therefore dimly visible when it is in eclipse, but copper-colored instead of yellowish white. The gradual change in color can be noticed for a considerable time before any part of the moon is in the complete shadow.

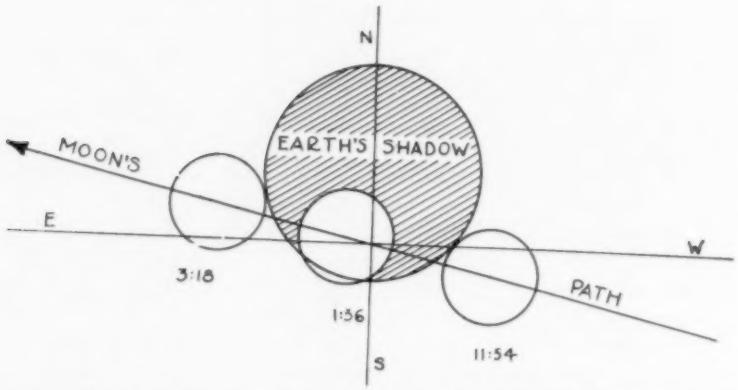
When the moon is near its position of greatest eclipse the part remaining lighted will appear like a shining support for a dim copper-colored balloon above it. On this uneclipsed portion there are the Doerful mountains, whose peaks reach 26,000 feet above their bases. In spite of their great altitude they are not separately visible without optical aid.

In pre-scientific days eclipses of the moon were regarded with superstitious awe, for apparently it was covered by some mysterious darkness coming out of the unknown. Yet the ancient Greeks understood fully the general relations of the sun and the moon and knew that lunar eclipses are due to the earth's shadow. At an even earlier date the Chaldeans had discovered from many centuries of records of the occurrences of eclipses of the sun and the moon that they recur under approximately similar circumstances in periods of 18 years and 11.32 days. With present knowledge of the motion of the moon the times at which eclipses will occur can be predicted almost to the second as long in advance as may be desired.



RELATIONS OF SUN, EARTH AND MOON FOR VARIOUS POSITIONS OF MOON

LETTER *S* REPRESENTS THE SUN; *E* REPRESENTS THE EARTH AND *a*, *M*, *b*, *c*, *N* AND *d* REPRESENT THE MOON AT VARIOUS POSITIONS, OF COURSE NOT IN TRUE SCALE. THE MOON AT *a* IS IN THE PARTIAL SHADOW OF THE EARTH, AT *M* IT IS TOTALLY ECLIPSED AND AT *N* IT ECLIPSES A SMALL SPOT ON THE EARTH.



PATH OF THE MOON THROUGH THE EARTH'S SHADOW ON OCTOBER 27–28
ON OCTOBER 27, 11:54 P.M., THE MOON IS IN THE EARTH'S PARTIAL SHADOW AND JUST ENTERING THE COMPLETE SHADOW. AT 1:36 A.M. THE ECLIPSE IS AT ITS MAXIMUM, AFTER WHICH THE MOON PASSES OUT OF THE SHADOW, AND FINALLY LEAVES IT AT 3:18 A.M.

Although eclipses of the moon are not of as great scientific importance as eclipses of the sun, yet they offer opportunities for several interesting investigations. The most important of the problems which are investigated at times of lunar eclipses is the temperature of the moon's surface at its midday. When the moon is eclipsed its day side is obviously toward the earth, for the sun and the moon, as seen from the earth, are in opposite directions. Therefore, just before an eclipse the visible portion of the moon has been exposed to the sun's rays for several terrestrial days, because the period of the moon's rotation is about four weeks. Since the moon has no atmosphere, its surface becomes highly heated during its long day. The question is to what temperature it is raised.

When the moon is eclipsed its day has been rapidly changed into night. Before eclipse the energy received from it by the earth is partly reflected solar energy and partly radiated energy. It is essentially impossible to separate the two. But during eclipse all the energy received from the moon by the earth is radiated heat. From measurements of this heat it has been found that the temperature of the moon's surface at its noon is about 250° F. During its long night of fourteen terrestrial days its temperature descends correspondingly low, possibly to two hundred degrees below zero. At least, during the relatively brief interval of a lunar eclipse it falls below the freezing point of water. The extreme range in temperatures on the moon would probably preclude the existence of life on its surface, even if there were no other very serious adverse conditions. F. R. M.